Best Management Practices
for
Golf Course
Development and Operation

Originally published by:
King County Environmental Division
January 1993

Scanned copy reprint

King County
Department of
Natural Resources and Parks
Water and Land Resources Division
201 South Jackson Street, Suite 600
Seattle, WA 98104

Best Management Practices
for
Golf Course
Development and Operation

King County Environmental Division

January 1993

Table of Contents

1.0 Introduction

Golf is currently one of the fastest growing participatory sports in the U.S. With this increase in recreational activity has come greater usage of existing golf courses and increased demand for development of new courses. The National Golf Foundation predicts that one new golf course must be built per day for the next 11 years to meet projected growth of the golf industry (Balogh, 1992). King County, for example, has had a documented shortage of golf courses since the 1970's; at present, there are approximately ten golf courses being proposed across King County. Consequently, King County anticipates a continuing series of golf course development applications and has developed this manual to respond to the environmental concerns commonly associated with golf course development and operation.

In addition to meeting one of many recreational needs of local residents, golf courses, when managed according to the recommendations in this manual can provide open space, neighborhood separation, visual amenity, and wildlife habitat. Successfully meeting these multiple objectives, however, requires an understanding of potential impacts associated with golf courses as a result of construction activities, planting of vegetation, the use of pesticides and fertilizers, and water consumption. These issues, and recommendations for addressing them, are the subject of this manual.

1.1 Objectives, Approach & Scope of Manual

This manual of best management practices (BMPs) has been prepared to provide technical information to golf course planners, engineers, developers, biologists, landscape architects, government administrators, county residents, and the numerous other consultants and scientists that are involved or interested in golf course development and management. The objective of the manual is to review, compile, select and summarize existing technical data relating to golf course development and management. Particular areas of concern, and the focus of the BMPs recommended here, include water consumption and conservation, vegetation and wildlife habitat, hydrology and water quality. The manual also attempts to place the location and permitting of golf courses within a local and regional context of land use planning and environmental review processes.

The intent is to provide an up-to-date body of knowledge of golf course management practices that can provide guidance to those involved in golf course planning, design, management and permitting. It is hoped that the manual will result in greater direction and consensus on a number of management approaches and, as a result, reduce the time and uncertainty associated with current planning and review of individual proposals. While the recommended approaches are not likely to solve all environmental problems associated with golf courses, they can help identify thresholds of concern for particular issues, provide valuable guidance on how to deal with specific situations, and provide direction on how to plan for and mitigate specific impacts. It is also hoped that use of the manual will lead to development of a more coordinated process for reviewing golf course proposals.

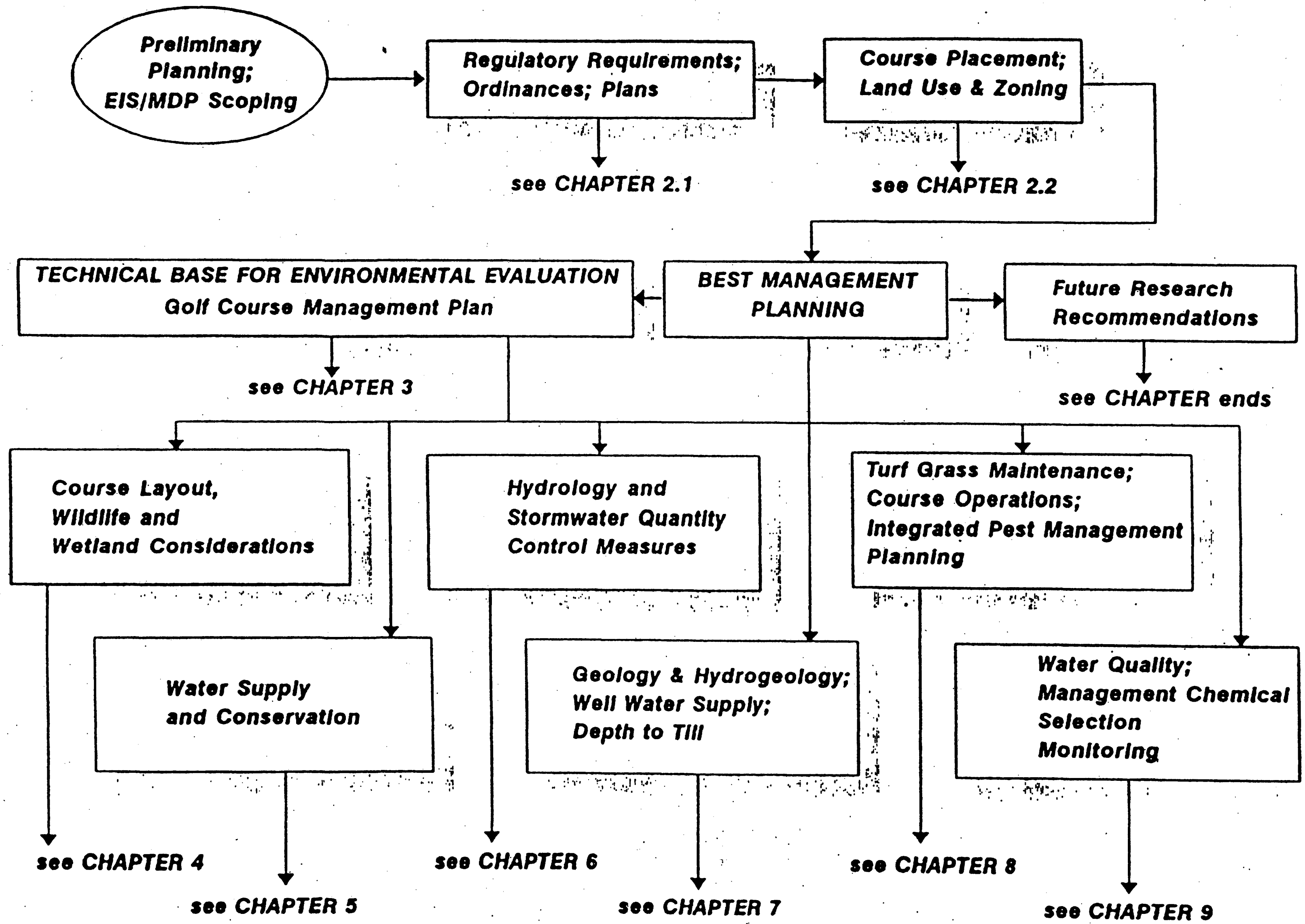
The manual contains technical information compiled from numerous sources; a bibliography is included for readers interested in examining the source material or in conducting further research. The contents do not purport to be exhaustive; rather, they are meant to provide a reasonable and useful level of detail concerning the major issues. New information relevant to golf courses is continuously being generated as a result of further research and experience across the country. This manual should be updated regularly to reflect and incorporate new information.

1.2 Content and Organization of the Manual

The manual is organized in ten sections plus appendices, with flow charts provided at the beginning of each section. In general, the organization follows technical subject matters (e.g. water); extensive cross references are provided to indicate relationships between technical issues. The Introduction provides an overview of the objectives, approach and scope of the manual. Section 2 provides an overview of relevant King County land use plans, policies and regulations related to golf course location and design, and includes a survey of land use adjacent to golf courses in King County. It also discusses the relationship of golf course planning to environmental review pursuant to the State Environmental Policy Act (SEPA) and King County's review of storm water management plans. Section 3 provides a model outline for a golf course management plan. Section 4 covers wildlife and habitat concerns, including wildlife management, use of native vegetation, use of buffers and special protection areas, and issues related to ongoing monitoring. Section 5 discusses water supply issues, including design of golf course irrigation systems and approaches to water conservation. Sections 6 and 7 address hydrology and control of water quantity, and geohydrology respectively. Section 8 contains information on turfgrass maintenance including integrated pest management. Section 9 recommends BMPs for protecting water quality, and addresses issues related to use of chemicals, simulation modeling to identify potential water quality impacts, and monitoring programs. Section 10 provides recommendations for future research, including development of a model for wetland and stream recharge, and approaches for predicting stormwater quantity and quality. Section 11 contains a comprehensive bibliography of sources for the manual and other references identified in local libraries.

The manual has been designed in a loose-leaf workbook format to provide for easy updating and to allow for notes and annotations in the margins. It is hoped that continued funding will be available to keep the information on BMPs current and to achieve a true "state of the art" BMP manual over time.

GOLF MANUAL ORGANIZATION AND FLOW CHART



1.3 Acknowledgments and Credits

The impetus for development of the BMP manual was provided by the King County Environmental Division and a steering committee consisting of public and private sector representatives. Funding for this project was also shared by these participants. Members of the Steering Committee are identified in Appendix A. Initial drafts of the manual were reviewed by a Technical Advisory Committee, identified in Appendix B, consisting of individuals knowledgeable in the technical areas involved in golf course development and operation. The authors wish to thank all these individuals for their valuable input.

The research and writing for the guidebook was performed by a team of consultants lead by Beak Consultants Incorporated (Golf Course Management Plan - Chapter 3, Water Quality - Chapter 9), and included the following firms: Associated Earth Sciences, Inc., (Geology & Hydrogeology - Chapter 7); W. Lee Berndt, Ph.D. (Operations and Pest Management - Chapter 8); Huckell/Weinman Associates, Inc. (Introduction - Chapter 1, Land Use - Chapter 2, manual design and editing); Northwest Hydraulic Consultants, Inc. (Hydrology - Chapter 6); and Springwood Associates (Wildlife - Chapter 4). Pesticide selections cautions in Chapter 9 were authored by Henry Shaw of the King County Environmental Division. Cover graphics were designed by Wendy John, Technical Graphics.

2.0 Land Use Planning & Regulatory Framework

2.1 Land Use Planning & Regulation In King County

This section provides a brief overview of major plans, policies and regulations affecting the location, development and operation of golf courses in King County. The intent is to identify the plans or regulations, succinctly summarize their intent and approach, and indicate their relevance to the concerns of this manual. Reviewing golf course proposals is extremely complex, both for applicants and County staff. There is uncertainty, for example, over when in the process some environmental data should be submitted and at what level of detail (e.g. conceptual or detailed). This section will, it is hoped, encourage continuing dialogue between interested parties over how study requirements and review procedures can be better coordinated.

Overall Planning Framework

Over the past fifteen years, King County has developed a three-part planning system, consisting of the County-wide Comprehensive Plan, adopted in 1985; community plans for thirteen identified community planning areas within the County; and functional plans for specific County services and facilities (such as storm water management, parks and open space, roads, economic development, etc.). The Comprehensive Plan establishes general policies on issues of regional concern, such as the overall land use pattern and general locations of areas appropriate for urban and rural levels of development, parks and open space, and resource uses (such as agricultural and forestry). General policies deal with subjects such as housing, commercial and industrial development, environmental protection, resource lands, public facilities and services, and transportation and utilities.

Community Plans develop more detailed policies, land use designations, development standards and capital improvement programs for distinct planning areas. When adopted by the County Council, they augment and amend the Comprehensive Plan. Functional plans, such as the King County Open Space Plan, develop policies and standards and recommend implementation programs for particular services and facilities.

Plan policies are implemented through land use regulations, such as the Zoning Code (particularly the Sensitive Areas Ordinance portion of that code) and through standards for environmental protection at the project level, like the Surface Water Design Manual. In addition, the State Environmental Policy Act (SEPA) overlays all of these plans and regulations and requires disclosure and mitigation of significant adverse environmental impacts.

These multiple plans, policies, regulations and standards were generally developed independently over the course of a number of years and may overlap, or sometimes appear to conflict, with one another. When they converge during the review of a particular proposal, such as a golf course, resolution of policy and regulatory conflicts can be time consuming, costly and stressful for both applicant and reviewing staff. Development of a particular site for recreational use, for example, may conflict with requirements for environmental protection. One purpose of this manual is to provide some tools for identifying and resolving such conflicts, for coordinating review of applications for golf courses, and for suggesting planning and management approaches that can deal with potential environmental problems.

Public Benefit Rating System

The Public Benefit Rating System provides an incentive available to landowners in King County and can be applied to golf courses. It is designed to preserve high quality open space meeting specified requirements. Land proposed for acceptance into the program must meet the definition of a "priority resource" as stated in Ordinance 10511. Active and passive recreation areas fall into this category, which may be applicable to golf courses. To satisfy the definition, a facility must be open to the public and charge a fee no higher than that charged by a comparable public facility; or, the facility must provide recreation or other services to youth, senior citizens, the handicapped or similar group. Ordinance 10511 lists a golf course open to the public, with fees not exceeding public golf courses, as an example of an eligible site. A golf course may also provide one or more of the other priority resources listed in the ordinance, such as significant wildlife, plant or salmonid habitat area or a surface water quality buffer area.

A golf course that meets the definition of a priority resource may apply for a tax reduction for the qualifying portion of the property. Landowners may receive an additional tax reduction for providing public access (unless it would endanger the resource). Public access is not required for most resources, however.

It should be noted that eligibility for the program requires use restrictions beyond those required by the Sensitive Areas Ordinance, or those in other King County regulations applicable to land use or surface water protection.

King County Comprehensive Plan

A number of policies in King County's Comprehensive Plan (1985) recognize the importance of open space and recreational facilities, consistent with other County policies and plans. The plan contains an Open Space land use category, for example, which identifies public park and recreation areas and environmentally sensitive lands protected by regulations. The multiple functions of these lands include providing visual buffers within and between areas of development, visual enjoyment and opportunities for outdoor recreation ,and protection of environmentally sensitive areas (PC-113).

The goal of the Comprehensive Plan's Environment and Open Space Element is to balance the need to accommodate future growth while, at the same time, preserving the region's highly prized environmental quality, recreational opportunities, and aesthetic beauty. The plan encourages achievement of multiple open space benefits where possible, including recreational opportunities, scenic vistas and wildlife habitat (E-202).

Private open space, such as that contained within residential communities, is encouraged as a means to achieve the plan's open space objectives. Private open space can protect valuable natural features, provide natural buffering, and reduce pressure on the County to provide publicly funded recreational facilities (E-208).

Community Plans

As noted above, Community Plans contain more specific policies and land use designations applicable to defined areas within the County. Each plan also develops recommendations for meeting the community's capital facility needs, such as for parks and roads. These plans also apply zoning classifications to all lands within each community planning area. Community plans can have an important influence on the location of specific uses, such as golf courses, through application of land use and zoning designations, through identification of environmentally sensitive areas, or through specification of development conditions in response to locally identified environmental problems.

King County Open Space Plan

King County's Open Space Plan (1988) is intended to achieve a dynamic and interrelated open space system that embodies a number of attributes or values. These important attributes include wildlife habitat, shoreline access, wetlands, regional trails, and scenic resources/community separators. Depending on specific location and physical conditions, golf courses may embody many or all of these attributes. The plan itself is focused on public acquisition of elements of the regional open space system, and on providing pedestrian/equestrian trail linkages.

King County Zoning Code

King County's Zoning Code implements the policies of the Comprehensive Plan and determines the permitted use of all land within unincorporated areas. It is, therefore, one important determinant of where golf courses can and cannot be located.

Currently, the code permits golf courses outright in most residential zones (RS, RD, RM) and as a conditional use in the Rural Area (AR) zone Golf courses are prohibited in resource zones (A, F, FR) and in commercial/industrial zones (BN, BC, CG, ML, MH, BP, QM). They are permitted as conditional uses in the Growth Reserve (GR) zone.

It should be noted that King County is currently considering an update of its zoning code. In the draft code (September 23, 1992), golf courses would be permitted outright in the Urban Reserve and Urban Residential zones, conditionally permitted in the Rural Residential zone, and prohibited in Commercial/Industrial zones (Neighborhood, Community and Regional Business, Office, and Industrial) and Resource zones (Agriculture, Forest, Mineral Extraction).

Sensitive Areas Ordinance

King County's Sensitive Areas Ordinance (SAO) (1990) is intended to protect environmentally sensitive areas, including wetlands, streams, steep slopes and landslide hazard areas, coal mine hazards, flood hazard areas and erosion hazard areas. The regulations generally establish setbacks, mitigation planning, and in some instances may limit activities and uses occurring on a site. The SAO's wetland regulations also establish protective buffer areas adjacent to wetlands. Activities that can occur within the buffers are limited.

In terms of golf course planning and design, some sensitive areas -- such as wetlands, streams and steep slopes -- may appear to be potential amenities, adding visual diversity and challenge to the golfer. At the same time, inappropriate activities in or near these sensitive areas can adversely affect the functions and values of the resource area. The challenge to the course designer and manager is to recognize and plan for the needs of the environmental feature along with recreational appeal.

King County Surface Water Design Manual

King County's Surface Water Design Manual (1990) establishes technical guidelines, standards and specifications for stormwater management and control. The manual describes drainage plan review procedures and application requirements for development projects, along with technical discussions of hydrologic analysis, hydraulic analysis and design, and erosion/sedimentation control plan and management practices. The "core" requirements of the manual include provisions for discharge location; off-site analysis; runoff control; conveyance systems; erosion/sedimentation control plans; maintenance and operation; and bonding/liability. A number of "special" requirements apply to critical drainage areas; requirements for master drainage plans; compliance with adopted basin or community plans; special water quality controls; use of oil/water separators; use of lakes, wetlands or closed depressions for peak rate runoff control; 100-year floodplain delineation; flood protection facilities for Type 1 and 2 streams; and geotechnical and soils analysis reporting requirements.

The Surface Water Design Manual serves to highlight the integral part that surface water management plays in golf course planning and design. Golf courses will require drainage review and compliance with the manual's technical standards and criteria; in some cases, preparation of a master drainage plan (MDP) may also be required. Review of required plans will involve a number of King County Departments and Divisions, including Development and Environment Services and the Surface Water Management Division. (Note that the Surface Water Design Manual is being revised as of this writing; see Section 6.1).

State Environmental Policy Act

The State Environmental Policy Act (SEPA) provides a state-mandated framework for evaluating and disclosing the significant environmental effects of proposals. The law involves use of analytic environmental documents (e.g. Environmental Impact Statement, Mitigated Determination of Non-Significance) of varying detail, and public review and comment. An important objective is to integrate environmental values into governmental decision making processes (and into private planning as well). The law also provides agencies with legal authority to condition or deny proposals because of significant impacts that are not mitigated (i.e. avoided, reduced, compensated for, etc.). Environmental concerns raised pursuant to the SEPA process pervade local decision making.

Golf course location, development and operation can raise significant issues regarding water quality, wildlife habitat, environmentally sensitive areas, and geohydrology. If commenced in the early stages of project planning, SEPA can provide a means for identifying and resolving potential problems and conflicts before costly commitments of resources are made. At the same time, SEPA could provide a focus for better evaluating and coordinating the multiple standards, requirements and processes applicable to golf course development.

Conclusion

Golf courses are complex projects requiring consideration of numerous technical factors (i.e. planning, regulatory, scientific and engineering). The drainage review process depicted above underscores the need for a clear understanding of the proposal; the timing and content of King County requirements; coordination and reduction of redundancy between multiple agencies and permit processes (including SEPA); and consideration, integration and resolution of multiple issues (e.g. land use, wetlands, drainage, etc.). While such a reconciliation is outside the scope of this manual, it is recommended that it become the focus of a continuing dialogue between golf course applicants and agency staff.

An outline of this dialogue could include the following topics:

- the nature of the proposal (e.g. whether conceptual or construction-level in its present form, and where the proposal is in the review process);
- the relationship -- considering timing, scope, content and objectives -- of the proposal to SEPA review, required land use/zoning changes, master drainage plan preparation/review, sensitive areas special studies, other County review and approvals (e.g. clearing/grading, building permit);
- the type and extent of information required for SEPA review and its relationship to data needs and submittal requirements for the range of approvals;
- whether SEPA review is being phased; and
- the level of detail of analysis required for the proposal, considering its present stage of development and the permits and approvals sought.

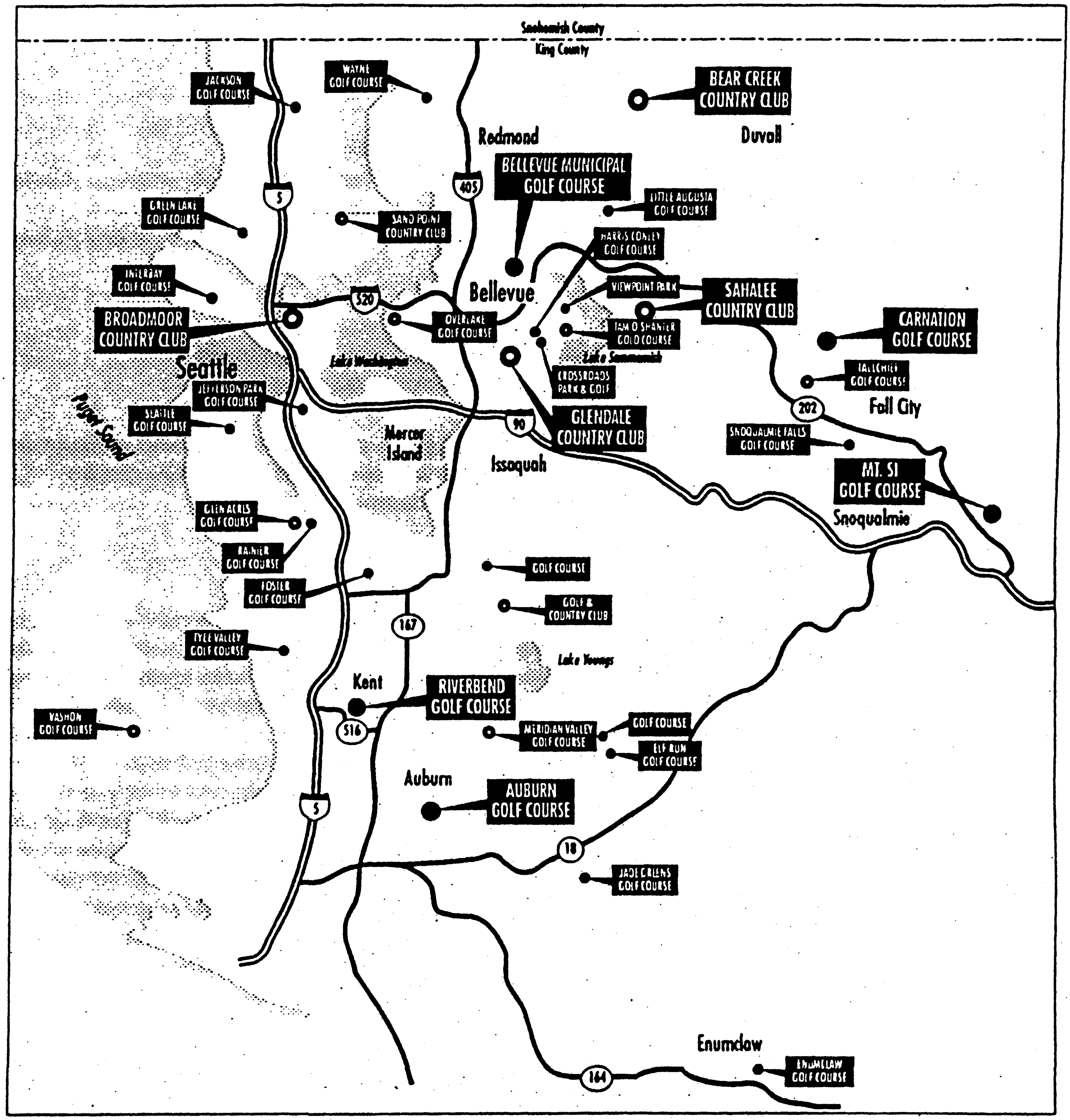
2.2 Land Use Patterns Adjacent to Golf Courses -- Results of a Survey

There are currently approximately 25 golf courses in King County (see Figure 2-1). Six of these are within the City of Seattle, with the remainder in unincorporated King County and the suburban cities. The courses are both publicly and privately owned; with one exception, all courses located in unincorporated King County are private. Golf's popularity as a recreational activity is increasing pressure for additional courses; a recent newspaper article, for example, identified ten golf courses in various stages of planning and permitting (Daily Journal of Commerce, 1992).

A survey of local golf courses was conducted in September, 1992 to identify any relationships between the location of golf courses and patterns of adjacent land uses. The eight courses examined in the survey are all located in King County, and were selected to represent a range of locations (urban, suburban, rural), settings (within a subdivision or planned community or free-standing), age (ranging from the 1920's to the 1980's), and ownership (municipal and private). A site visit was made to each to observe land use patterns. The courses identified below -- along with their year of opening, ownership and general location -- were included in the survey:

Urban Locations --

- Bellevue Municipal Golf Course (1968) - public (Bellevue)
- Broadmoor Golf Club (1929) - private (Seattle)
- Glendale Country Club (1956) - private (Bellevue)



Legend

INCLUDED IN THE SURVEY
- Public Course
- Private Course

NOT INCLUDED IN THE SURVEY
- Public Course
- Private Course

N

Not to Scale

Source: HUCKELL/WEINMAN ASSOCIATES, INC., 1992.

FIGURE 2-1

Golf Courses in King County

- Riverbend Golf Complex (1961/1989) - public (Kent)

Suburban Locations –

- Auburn Golf Course (1940/1969) - public (Auburn)
- Bear Creek Country Club (1981) - private (Bear Creek, within a planned community)
- Sahalee Country Club (1969) - private (East Sammamish, within a planned community)

Rural Locations –
- Mt. Si Golf Course (1927-1930's) - public (North Bend)
- Carnation Golf Course (mid 1960's) - public (Carnation)

Although the survey was not intended to be scientific, the courses examined are believed to represent the variety of golf course development in King County. The courses examined are generally described below.

Urban Area Courses

Urban area courses surveyed included the Bellevue Municipal Course, the Riverbend Golf Complex in Kent, the Glendale Country Club in Bellevue, and the Broadmoor Golf Club in Seattle. In general, adjacent land uses appeared to follow an identifiable pattern depending on whether the course was public or private.

Land uses surrounding the two public courses included some higher-density (4 - 6 units per acre), more modest single-family units, and a large number of apartments. The single-family homes represented older development, probably built in the 1960's - early 1970's. New development primarily consisted of apartments, with some commercial and office uses also located in the general vicinity. In one instance (Kent), a motel (and the City's commercial center) are located in close proximity to the course; other recreational facilities are also clustered near this course. In general, public courses tended to be highly visible from adjacent streets, due to moderate levels of screening.

The private urban courses surveyed were generally associated with lower density, higher priced single-family developments. Most of the residential development appeared to have been constructed shortly after the golf course was installed. At one course, it appeared that several large lots were being redeveloped with new, large single-family homes on smaller lots. Some apartment housing was located in the vicinity of the course, along a major arterial that bordered one side of the course.

Suburban Area Courses

Suburban courses included in the survey included the Sahalee and Bear Creek Country Clubs, both developed in a planned manner in conjunction with surrounding residences, and the Auburn municipal golf course. In general, land uses surrounding suburban golf courses were predominantly single-family residential. The major difference between public and private courses appeared to be the size and apparent market value of adjacent residences.

The Auburn course is located in the floodplain of the Green River, at the foot of a steep escarpment. The residential areas across the river consist primarily of subdivided lots developed at a density of about 4 units per acre; some duplexes are also located along the river. Older, large lot residential areas are located on the plateau above the course. Some redevelopment appears to be occurring as lots on the plateau are being subdivided and new, large homes constructed.

Both the Bear Creek and Sahalee Country Clubs are generally surrounded by exclusive developments of high-priced "executive" homes (3,500 square feet and up). In some instances, older residences located on 5-acre lots are still evident adjacent to new subdivisions. These areas appear to be in transition from older, "rural" residential types of neighborhood to suburban (one to two units per acre) development.

Rural Area Courses

The Mt. Si (North Bend) and Carnation golf courses were surveyed as representative of golf courses in rural locations. Much of the land adjacent to both courses is farmland. At Mt. Si, a small cross-roads commercial/residential area is located northwest of the course. Several residences are located to the north across the river. These residences are generally located on large lots, and include mobile homes, smaller residences, and larger, newer rustic homes. The Carnation Golf Course is adjacent to farms and wet pastures. Some new single-family residences have been developed on the ridge west of the course.

Findings & Conclusions

Based on observed land uses in the areas surveyed for this analysis, there does appear to be a relationship between golf courses and adjacent land use patterns. In part, this relationship depends on the ownership of the course (public or private) and whether it was planned and/or constructed in conjunction with other uses. In general, the areas examined were predominantly residential in character; commercial uses, for example, are infrequently located adjacent to golf courses. Higher density residential and non-residential uses were observed adjacent to Kent's municipal golf course. This pattern appears to implement a local plan to cluster complimentary activities -- including other recreational uses -- along a major arterial. Kent's municipal course is also proximate to the Central Business District and more intensive commercial uses.

Location of a golf course seems to support establishment and maintenance of residential character; most of the areas surveyed appear to be relatively stable in terms of land use. Based on observed development patterns adjacent to older (particularly private) courses, the size and apparent cost of nearby housing appears to be related to course ownership -- private courses are generally surrounded by expensive homes on relatively large lots. From a land use planning perspective, location of a golf course also seems to provide an opportunity to coordinate nearby residential development to capitalize on the amenity/recreational value of the course. This observation is also confirmed by the location of golf courses within master planned communities (e.g. Harbour Pointe and Mill Creek) as an open space and recreational element. The same land use relationship may occur with public courses, however, based on observed land use patterns in the City of Kent.

Public courses tend to be located adjacent to major arterials and to be relatively more visible. Private courses, on the other hand, are often located away from the street, within the interior of a community.

2.3 Land Use Considerations in Golf Course Siting and Design

General Observations

Golf courses require large amounts of land (generally 100-250 acres), and land needs and cost are an important determinant of their location. They are often constructed on old farms in transitional areas (i.e. on the suburban fringe) or in floodplains because of greater land availability and lower land cost. These sites may contain extensive environmentally sensitive areas, such as wetlands or unstable soils. While these features may appear as amenities or "challenges" to course designers and golfers, they also function as development constraints in terms of many local land use regulations.

For developers, a golf course can also form the focus of a residential community. Many of the ten golf courses currently proposed within King County, for example, are located within subdivisions, planned unit developments (PUDs) or master planned communities (MPDs). While expensive to construct and maintain, golf courses and other recreational amenities are valuable planning and marketing features; they can add to the value of homes, help create the opportunity for a desired lifestyle, and provide an important marketing tool for the project. At the same time, the cost of golf course construction is typically divided among the residential lots in the development; this tends to make adjacent housing more expensive.

For the host community or neighborhood, a golf course provides a significant amount of open space, a visual amenity, and a means to define and separate neighborhoods or developed areas. Depending on location (and on applicable plans), golf courses can function as a valuable link in planned local and regional open space systems. They can also meet a portion of recreational demand and help relieve local government of the cost of providing recreational facilities. In general, then, the challenge and opportunity presented by golf course proposals is to locate and design them to meet multiple objectives -- open space, environmental protection, wildlife habitat, and recreation.

Land Use Issues

The initial consideration is finding adequate land. Large land requirements (100-250 acres) tend to push courses to the suburban fringe or to rural areas, where large amounts of land are available at reasonable cost. While locating parks and open space as close as possible to urban populations may be desirable from a planning perspective (i.e. to create self-contained communities and to reduce auto travel), it is not feasible to locate a golf course in a developed urban neighborhood or in suburban areas with checkerboard land use patterns.

At the same time, location decisions should be compatible with local land use patterns. As indicated in the survey, golf courses can be an important element of local land use character and can be planned to establish and reinforce particular patterns. Compatibility with adjacent activities and community character, and relationships to planned land use patterns, should be important threshold considerations in golf course siting, particularly in suburban and rural settings.

In the minds of some residents, golf courses represent a potential for risk of injury or property damage (i.e. from miss-hit golf balls), trespass and loss of privacy. Physical risks can be addressed in golf course design and building placement/orientation, particularly for new courses within subdivisions and planned communities. Screening and buffering with vegetation or fences, or changes in elevation, can also help to maintain individual privacy and reduce opportunities for trespass.

Golf courses also use significant amounts of water for irrigation (see Chapter 5). Course developers should consult with local water purveyors to ensure sufficient water supply is available for expected demand.

Probably the major land use consideration encountered by golf course proponents - relevant to both course siting and design -- is compliance with regulations for wetlands, streams, floodplains, unstable or erosion-prone lands, and other environmentally sensitive areas. Proposals to alter or disturb these areas, or to integrate them into course design, may result in tension between the applicant's desire to design a course that is challenging, varied and aesthetically pleasing to the golfer (and/or integrated into a planned community), and the agency's mandate of protecting the functions and values of natural resources. This situation also can provide an opportunity for mediating conflicts and attempting to accommodate multiple objectives.

Finally, despite the potential benefits identified above, golf course proponents should note that some neighborhoods may view the location and construction of a golf course negatively. The recommendations in this manual can help to identify and mitigate potential adverse effects on land use and the environment.

Section 3.0 Golf Course Best Management Practices and Planning

3.1 Golf Course Management Plan

This section contains a recommended outline for a Golf Course Management Plan (GCMP). The plan should serve as an overall guide for proper construction, maintenance and management of golf courses. Elements of the plan include: integrated wildlife/botanical management planning, construction phase issues, irrigation water use, course management and maintenance operations, integrated chemical management, water quality provisions, and monitoring. An Integrated Pest Management (IPM) is a particularly important component of the management plan. The IPM should incorporate the Best Management Practices identified in Chapter 8 of this manual.

The GCMP should be prepared in four phases; these are defined to coordinate the detail of information developed during the planning of golf course proposals with the requirements of King County's review of permit applications. The numbers used in the table below correspond to the phase of planning (1-4); the key indicates the general timing of preparation and submittal of information. Phase 1 would be completed in the context of the SEPA review process and, if applicable, in preparing a Master Drainage Plan (MDP) according to King County criteria. Phase 2 would be incorporated into the grading/construction plans for the proposed golf course. Phase 3 would be provided in conjunction with a commercial building permit. Phase 4 would entail completion of a general management manual for the course, with direct input from the golf course superintendent (who is typically not identified until this point in the process).

Key:
1. Provided in the SEPA checklist, EIS and or MDP document
2. Provided at time of grading permit application
3. Provided with commercial building permit application
4. Provided prior to final operational permit issuance

Wildlife/Botanical Management Planning Integration

1	2			Course layout and design on the site
1	2	3	4	Maintenance staff responsibilities to wildlife management/ maintenance
	2	3		Public/player education
1	2			Buffer width, buffer value to wildlife/water quality
1	2			Specific areas of buffer thinning or wetland overstory thinning (if any)
	2			Aesthetic plantings/species composition

Construction Phase Concerns

1	2			Clearing, grading and site stabilization summary (refer to TESCP)
1	2			Fill dirt/spoils dirt sources & contaminant screening
	2			Optimum seeding date
	2			Turf seeding mix

Irrigation Water Use

1	2			Sources and supply
	2			Initial planting consumption/proof of short-term renewable supply
	2			Seasonal consumption/proof of long-term renewable supply
	2			Water minimization features (irrigation system, arid turf, native species, water reuse, gray water use, seasonal planting to maximize natural rainfall)
1	2			Irrigation system(s)
	2			Type of irrigation system and efficiency
	2			Method/scale of determining irrigation requirements on course
	2			Surface reservoirs (if any)

Course Management Provisions

1	2			Key staff position qualifications/experience
1	2			Education and training of key maintenance positions

Course Maintenance Operations

	2	3		Location/size of turf/greens growth areas
	2	3		Location/size of operations yard
1	2	3		Fueling and fuel storage provisions
1	2	3		Maintenance building drainage
1	2	3		Fueling and equipment wash-down catchment isolation and disposal
1	2	3		Traffic and maintenance roadways; drainage stream crossings
	2		4	Maintenance staff responsibilities for oil/water separators, other water quality features within maintenance yard or course
	2		4	Artificial lakes management plans/categorization of lakes
1	2		4	Turf maintenance - mowing and thatch/disposal practices

Integrated Chemical Management Plan (Pesticides and Fertilizers)

	2		4	Cultural practices to minimize use of pesticides/fertilizers
	2		4	Identification of turf tolerance levels for pests
	2		4	Pest identification and test kit measurement techniques for pest levels
	2		4	Use of pest prediction models

	2	4	Identification of likely target pests & prioritized methods of treatment
	2	4	Maintenance chemical identification; application amounts; application targets; application provisions; application prohibitions
	2	4	Identification of chemical toxicity, transport and degradation potential
	2	4	Identification of chemical application methods
	2	4	Identification of potential chemical hazard to staff and public
	2	4	Chemical storage and transfer provisions: - Tracking and disposal provisions - Storage facility/pesticide mixing area/separation of chemical classes/sump drainage - Emergency spill provisions - Provisions for loading and clean-out of application equipment - Temperature, humidity control/other special requirements - Provisions for access limitation to storage/handling areas

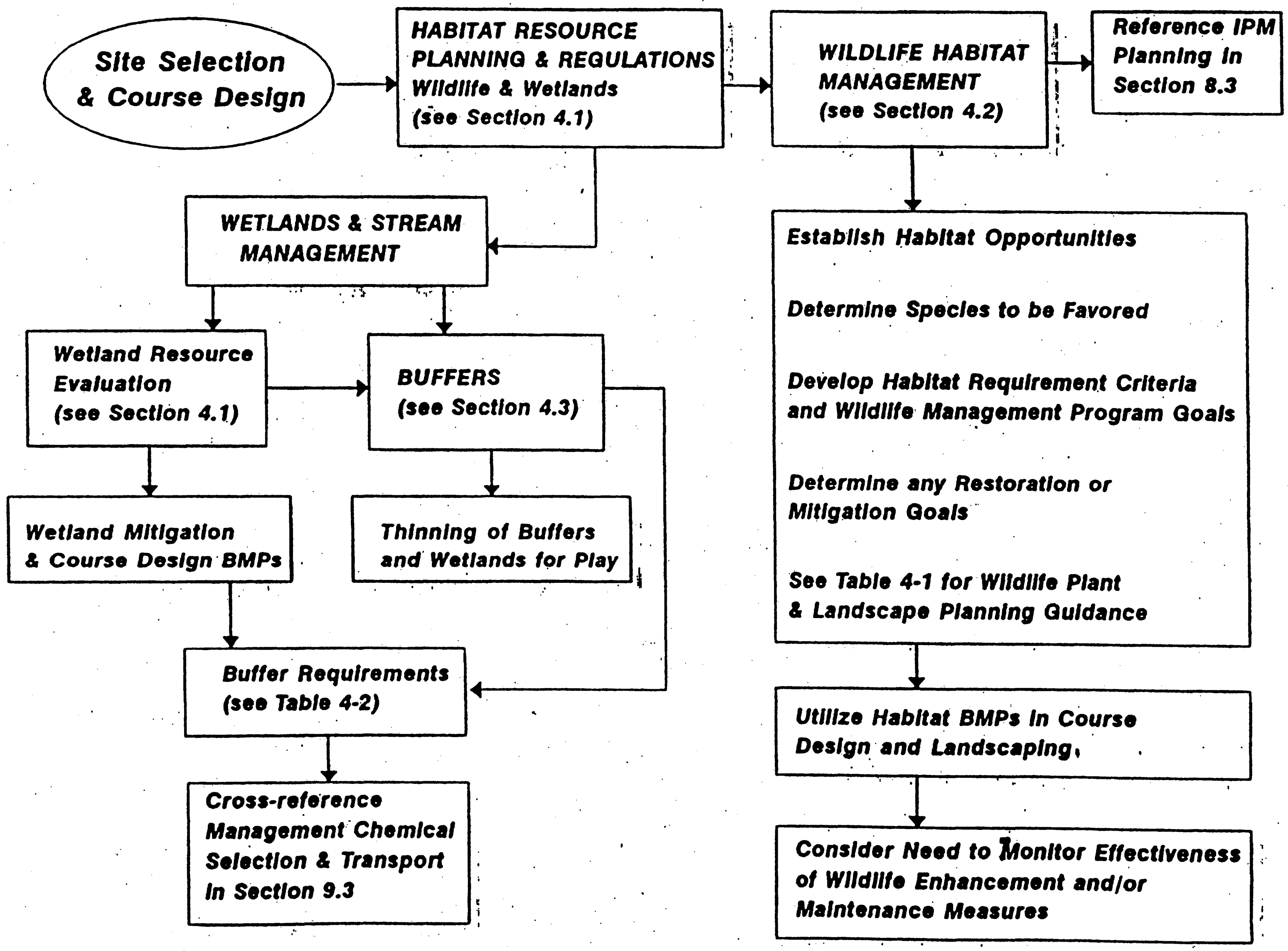
Water Quality Provisions

1	2	4	Impact estimation analysis -- chemicals/toxicity/seasonality/ application/mitigation transport potential (soils/groundwater/ interflow)/resource proximity
	2		Special protection areas, if any (determined by chemical transport potential, handling, proximity, sensitivity); criteria for designation
1	2		Protection facilities description (e.g., liners, catchment sequestering, sumps, GAC filters) - Design criteria - Maintenance provisions (including disposal if applicable) - Performance testing (see also monitoring)

Monitoring

2		Tie-in to monitoring programs required under the SEPA and MDP process for water quality, quantity, fisheries and/or wetlands, if any, for associated development (if any)
2		Manual for integrated monitoring of water quality, quantity, fisheries and/or wetlands as warranted; criteria, timing, performance guarantee
2	4	Inclusion of specific monitoring plans for artificial lakes, if any, with potential for drainage or irrigation use to site
2		Inclusion of specific monitoring plans for pesticide and fertilizer transport from course
2		Identification of specific monitoring provisions for special protection areas, if any
2		Demonstration of feasibility to respond to monitoring findings if necessary

CHAPTER 4 FLOWCHART - Wildlife Habitat



Wildlife Habitat

Summary of Best Management Practices

- Determine if the proposal can be accommodated by avoiding or minimizing impacts to environmentally sensitive areas, such as wetlands, riparian corridors and other habitat areas.
- Where mitigation is not practical or feasible, avoid sites with substantial environmental constraints.
- Locate high use areas away from sensitive habitats to reduce impacts of noise and other disturbances.
- Course layout should include upland buffers to serve as transition zones between active use areas and wildlife habitat.
- Maintain sources of food, water and shelter for local wildlife populations.
- Design roughs and naturally vegetated strips to provide linkages between habitat areas.
- Maintain access for migratory species to habitual routes, food sources and breeding grounds.
- Preserve and maintain native vegetation.
- Avoid use of exotic vegetation that is poorly adapted to local conditions and requires intensive maintenance.
- Retain mature significant trees, preferably in groups, where possible.
- Retain dead trees and snags, downed logs and brush piles within roughs.
- Identify wetlands and evaluate their functions and values according to adopted King County procedures.
- Avoid application of chemicals (pesticides, insecticides, fertilizers etc.) within wetlands and their buffers.
- Treat all surface water runoff (including sedimentation control) prior to discharge to wetlands or buffers.
- Avoid altering ground water flow patterns and other characteristics.
- Retain stream channels in a natural, unaltered state (consistent with King County requirements).
- Limit in-stream structures (such as bridges, piers, boat ramps or culverts) that impede wildlife movement.
- Implement an integrated pest management (IPM) program to minimize impacts of pesticides and chemicals.

4.0 Wildlife Habitat

Potential sites for golf courses often lie in transitional areas between suburban-rural zones. In King County, the landscape in this zone frequently consists of residential use, some commercial development, agricultural lands, and large tracts of open space dominated by second growth forest. Maple Valley, Black Diamond, and the East Sammamish Plateau are examples of these types of areas within King County where golf course development has been proposed.

Growth in the region has resulted in the fragmentation of wildlife habitats such as wetlands and riparian corridors. Golf courses can contribute to this fragmentation. If implemented diligently, however, wildlife best management practices can help minimize these impacts by integrating wildlife concerns with golf course planning. Potential results of this approach can include creating valuable open space, linking green belts, and buffering wildlife habitat areas. If planned carefully, golf course development can capture opportunities for enhancement and protection of wildlife habitat and aquatic resources. The goal of habitat resource planning is to protect, preserve, restore, or enhance the structural, functional, and visual characteristics of natural systems. Feasibility for natural resource enhancement will be based on a site's potential to buffer remaining habitat, provide corridor linkages to facilitate the movement of wildlife, increase the diversity of available food and water sources, and increase the structural diversity of vegetation communities.

This chapter focuses on planning strategies and management practices that can minimize the impacts of golf course development on wildlife habitat. It also provides an overview of federal, state and local regulations and guidelines designed to protect valuable habitat.

4.1 Planning for Wildlife Habitat in Golf Course Development

Golf course planning consists of five phases: site selection, design, construction, course establishment, and on-going maintenance. It is critical to thoughtfully plan for habitat protection during initial site selection and throughout course design to mitigate impacts during construction and operation. Comprehensive planning begins by identifying the habitat resources and their appropriate buffer requirements on and off the site proposed for development. Information should be obtained from King County and the Washington State Departments of Wildlife and Fisheries about priority habitats that may exist on the proposed site prior to final site selection.

Typical habitat resources encountered include wetlands, riparian corridors, lakes and ponds, pastures and mature second-growth forest. These ecosystems provide a rich variety of habitats for insects, amphibians, fish, birds, and mammals. Identifying these habitats is the first step. Sources of information regarding the location and types of wildlife habitat include data bases maintained by the Washington Department of Wildlife (WDW), which includes the Priority Habitats and Species (PHS), the Heritage Data Base, Washington Rivers Information System, and the Lakes of Washington Fish Data Base. Additional mapping of habitat areas is available from the National Wetland Inventory Maps, the King County Sensitive Areas Folio (1990), and the King County Wetlands Inventory (1983). Site-specific studies and habitat mapping, conducted according to King County guidelines, may also be necessary.

One goal of layout design is to avoid or minimize impacts to natural resources on a site-specific basis. Once habitat areas are identified, the golf course planner should test the feasibility of alternative course layouts. Planning throughout the construction, course establishment, and on-going maintenance phases should first avoid impacts, then minimize and compensate or otherwise mitigate for impacts that cannot be avoided.

General Planning Strategies

Environmental concerns are a primary issue in the golf course site selection and permitting process. Sensitive planning can help protect and enhance wildlife habitat. Wildlife-related strategies that should be incorporated into golf course planning include the following:

- Sites with substantial environmental constraints -- where mitigation is not feasible or practical -- should be avoided.

- Determine if the course program can be accommodated by avoiding or minimizing site-specific impacts to ecologically sensitive areas such as wetlands, riparian corridors, and other sensitive wildlife habitats. Identify opportunities to enhance wetland functions and values.

- Course layout should account for upland buffers to function as transitional zones between areas left as wildlife habitat and areas programmed for more active use.

- Avoid disturbance to local wildlife populations by maintaining sources for food, water and shelter. Enhancement opportunities to increase access to food, water, and shelter should be explored.

- When possible, design roughs and naturally vegetated strips to provide linkages between areas retained as habitat.

- Maintain migratory species access to habitual routes, food sources and breeding grounds.

- Implement an integrated pest management (IPM) program to minimize the impacts of pesticide and chemical use.

- Avoid posing threats to wildlife directly or indirectly through increased air or water pollution.

- Locate high level use areas away from sensitive habitat to reduce the impacts of noise and human activities.

- Preserve and maintain native vegetation in its natural condition.

- Avoid the use of invasive or exotic vegetation which is poorly adapted to local conditions and requires intensive maintenance.

These strategies should be considered when selecting a site and implemented when planning and designing the course. Specific strategies are discussed in greater detail in this section.

Wetland Resources

Introduction

Large vacant sites suitable for golf course development are likely to be constrained to some degree by wetlands. Wetlands are generally defined as: "Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." This definition is derived from the Clean Water Act, the Federal Manual for Identifying and Delineating Jurisdictional Wetlands, the Growth Management Act, and the King County Sensitive Areas Ordinance.

Over the past decade, recognition of the important functions and values wetlands provide has resulted in increased federal, state, and local policy and regulation directed at wetlands protection. These functions and values, and existing regulatory programs, are briefly described below.

Wetland Functions and Values

The functions and values an individual wetland provides are determined by the vegetation character of the wetland and the surrounding upland, the position of the wetland in its drainage basin, the size of the wetland, and the degree of disturbance. In general, wetland functions and values include storm water detention and flood attenuation, water quality enhancement, ground water recharge and discharge, shoreline stabilization, wildlife and fish habitat, open space and recreational values, and educational opportunities. These functions and values can be diminished when wetlands become isolated by golf course features or disturbed by human activity.

Storm Water Detention and Flood Attenuation

Wetlands often occur in topographic depressions which detain water better than channelized water courses. Referred to as flood storage capacity, wetlands can lower peak runoff flows during a rainfall event. Well developed wetland soils often have a high organic matter content and, therefore, a high water retention capability. Such wetlands along rivers and stream courses act as large sponges, temporarily storing large volumes of storm water and gradually releasing it into receiving waters. This helps reduce local and downstream flooding by lowering peak flows and slowing the velocity of water. Wetlands provide a natural means of controlling the dynamic energy of flood waters which can cause downstream damage. By temporarily storing water at shallow depths within the soil and slowly releasing the stored water, wetlands help maintain stream flows during dry periods.

Water Quality

Wetlands provide important water quality benefits because of their self cleansing ability to trap sediments and filter pollutants. Surface water runoff from the surrounding landscape carries sediments which are trapped by the stems and roots of wetland vegetation. These sediments often carry excess pollutants and nutrients which can either be stored in wetlands and released over time, or are absorbed by wetland vegetation. This filtering activity helps purify water and can make a significant difference in downstream water quality.

Ground Water Recharge/Discharge

In some areas, ground water is an important (sometimes the primary) source of water for domestic consumption (see Chapter 5). Aquifer recharge is the movement of surface water down through the soil to the underlying ground water system. Wetlands that are connected to ground water are important because they allow water to infiltrate and replenish or "recharge" underground aquifers. This is especially important in areas where aquifers are threatened by decreased recharge and overuse or where aquifer depletion has the potential to cause saltwater intrusion; Saltwater intrusion is not presently a significant problem in King County. When the water table is high, wetlands can also act as ground water discharge areas.

Shoreline Stabilization

Wetlands help stabilize stream banks and shorelines by providing a buffer to the forces of wind and wave action. The wetland vegetation acts to dissipate the erosive energy of waves and currents and the roots provide additional stability by binding the soils and allowing a degraded shoreline to recover.

Wildlife and Fish Habitat

Wetlands are complex ecosystems with distinct communities of plant and animal life. As a transitional environment between aquatic and terrestrial ecosystems, wetlands often have high structural diversity and can support an abundance of wildlife. Many species of birds, fish, mammals, reptiles, amphibians, and insects use wetlands for breeding, rearing, food and shelter. Waterfowl and wading birds use wetlands in the Northwest as feeding grounds, over wintering areas, and breeding grounds while migrating. Wetlands provide year-round habitat for many species of birds and meet seasonal, life cycle needs for fish, insects, and amphibians. Mammals that use wetlands for food, water, and cover include otter, muskrat, beaver, deer, bear and bobcat. Wetlands provide a type of habitat that is extremely important to the habitat mosaic of the overall landscape; golf course development can fragment this habitat into isolated and less valuable components.

Open Space and Recreational Values

Wetlands have traditionally provided excellent opportunities for bird watching and photography due to the high diversity of plants and animals. Other active recreational uses wetlands provide include hiking, non-motorized boating, and fishing. Wetlands also afford relaxing opportunities for spending time in nature in a peaceful setting and, in rapidly urbanizing areas, provide important open space values.

Education

Wetlands are an educational resource rich in the possibilities for understanding and appreciating the natural world we live in. Students of all ages can benefit from studying wetlands. As diverse ecosystems, wetlands provide excellent opportunities to understand basic ecology, learn about the food chain, hydrology, soil science, botany, and much more. Wetland science has recently been recognized as a distinct area of study, with its own publications and professional groups.

Wetland Regulations

The National Golf Foundation has identified wetlands as the primary concern related to obtaining permits at local, state and federal levels of government across the U.S. Related environmental concerns include wildlife habitat, nitrates and chemical contamination, ground water protection, and pesticide usage. A summary of the complex federal ,state, and local laws protecting wetlands is presented below. It should be noted that for any project, federal, state and local wetland regulations may apply simultaneously.

Federal Programs

Wetlands are protected and regulated at the federal level as "waters of the United States" under Section 401 and 404 of the Clean Water Act (1972, 1975, 1987). Section 404 is jointly enforced by the U.S. Corps of Engineers (COE) and the U.S. Environmental Protection Agency (EPA). Under Section 404, the COE is authorized to issue permits for the discharge of dredged or fill materials into waters of the United States. Technical consultation and review of 404 permits are provided by EPA, the U.S. Fish & Wildlife Service (USFWS), and the U.S. National Marine Fisheries Service. The Washington State Department of Ecology is responsible for issuance of the 401 Water Quality Certification. Other federal laws regulating wetlands are contained in Section 10 of the Rivers and Harbors Act of 1899, the National Environmental Policy Act (1969), the Coastal Zone Management Act of 1972, Executive Order 11988 and 11990 (1977), the Food Securities Act of 1985 (Swampbusters), and the Water Resources Development Act of 1986.

State Programs

Laws and regulations in the State of Washington that address wetland protection include the Shoreline Management Act, the Growth Management Act, Hydraulic Project Approval, the State Environmental Policy Act, the Floodplain Management Program, and the Forest Practices Act. Policy documents that contain recommendations and standards regarding wetlands include Executive Order 90-4, the Puget Sound Water Quality Management Plan, and Department of Community Development's Minimum Standards.

King County Regulations

The King County Sensitive Areas Ordinance (SAO, Ordinance No. 9614, 1990) regulates the protection of wetland habitats in unincorporated portions of King County (and in incorporated areas where an interlocal agreement is in place).

Wetland Rating System

The King County SAO classifies wetlands as either Class I, II or III according to their size, value (benefit), quality (condition) and functions (i.e. what they do in the larger environment), as described below.

Class I Wetlands

- Wetlands which have received an Unique/Outstanding #1 rating in the King County Wetlands Inventory (1983), or

- Exhibit the presence of species listed by the federal or state as endangered, or threatened, or exhibit the critical or outstanding habitat for those species, or
- Have a component of 40% to 60% permanent water in dispersed patches with two or more classes of wetland vegetation, or
- Are equal to or greater than ten acres in size having three or more wetland classes (emergent, scrub-shrub, etc.), one of which is open water, or
- Exhibits the presence of plant associations of infrequent occurrence.

Class II Wetlands

- Wetlands which have received the Significant #2 rating in the King County Wetland Inventory (1983), or
- Are greater than one acre in size, or
- Are equal to or less than one acre in size and have three or more classes of wetland vegetation (emergent, scrub-shrub, etc.), or
- Are equal to or less than one acre in size and have a forested wetland class, or
- Have heron rookeries or raptor nesting trees.

Class III Wetlands

- Wetlands which have received the Lesser Concern #3 rating in the King County Wetlands Inventory (1983), or
- Are equal to or less than one acre in size and have two or fewer wetland classes (emergent, scrub-shrub, etc.).

Wetland Mitigation

When development will result in direct physical impacts to wetlands, a wetland mitigation plan must be prepared as part of the permitting process. Impacts are quantified, and a proposal to compensate for wetland function and value losses must be developed. Compensation requirements are dependent on the class rating of a wetland and the extent of impacts proposed. A wetland assessment report, documenting existing wetland functions and values, is used as a basis for identifying the impacts of proposed development on a wetland system. The golf course planner should first consider avoiding impacts by choosing an alternate site, design, or construction methods. If this is not possible, mitigation strategies should be considered to minimize impacts. Mitigation may consist of restoring impacted wetlands, enhancing existing wetlands, or creating new wetlands. Wetland restoration improves the conditions of existing degraded wetlands or reestablishes wetland habitat in areas they once occupied. Wetland enhancement involves improving the functions and values of an existing wetland. Wetland creation is creating a new wetland from an upland site to replace wetlands lost to development.

Planning Strategies

The following strategies should be considered and incorporated in golf course planning.

- Wetlands on proposed golf course sites should be identified and evaluated for their functions and values.
- Determine the minimum required buffer width for each wetland and incorporate into design. Determine if the minimum buffer widths are consistent with wildlife management objectives. (Note that in some instances the minimum buffer may not be adequate to protect the wetland from probable impacts associated with golf course development.)
- Course layout should evaluate and avoid impacts to wetlands and their buffers.
- Treat all surface water runoff prior to discharge into the wetland and its buffer.
- Avoid alteration of flow patterns, salinities, and other characteristics due to proposed changes in ground or surface hydrology.
- Provide sedimentation control facilities prior to discharge into the wetland and its buffer.

Habitat Protection and Wildlife Enhancement

Wildlife Habitat Regulation

Golf course planners will need to identify wildlife habitat present on potential sites. The Washington State Department of Wildlife (WDW) has identified what it considers to be habitats of high priority, i.e. those associated with wildlife species that receive varying levels of protection. Priority habitats include wetlands, riparian corridors, meadows, islands, aspen stands, old growth and mature forests, oak woodlands, snag-rich areas, talus slopes, shrub-steppe, urban natural open space, caves, and cliffs. The value of any given habitat is elevated to priority status if the area possesses one or more of the following attributes:

- comparatively high wildlife density,
- high wildlife species richness,
- significant wildlife breeding habitat,
- significant seasonal ranges (migratory species),
- significant movement corridors for wildlife, and
- limited availability, and/or high vulnerability.

Although the WDW does not directly regulate these habitats, it has developed management recommendations (e.g. for buffers). The U.S. Endangered Species Act also regulates species listed as threatened or endangered. Currently, King County has not adopted distinct regulations for wildlife habitat (apart from wetlands); the County is currently drafting SEPA wildlife guidelines.

Habitat Basics

Three basic components are required to establish viable wildlife habitat: food, water, and cover. Food sources include insects, seeds, nuts and berries. Water is available from aquatic resources (ponds, wetlands, and streams). Vegetation provides opportunities for shelter, nesting, breeding and avoiding predators. Structural diversity throughout the full range of vegetative layers contributes to value of the habitat. The value of the wildlife habitat is highest when the understory (groundcover), midstory (shrubs), and overstory (tree canopy) are all present in a broad habitat area, although specific species will prefer or require specific proportions of these as habitat.

Spatial Requirements

Each species has a minimum amount of habitat area which it needs to sustain itself. If a habitat area falls short of this minimum, the species requiring that minimum area is not likely to be found. The size of a given habitat area also influences the amount of species diversity to be expected. It is generally believed that increasing a habitat unit by a factor of ten will yield twice the number of species supported by the habitat. Conversely, reducing a habitat area by half will reduce the number of species the area will support by one-tenth (Wilson, 1989).

The shape of a habitat area, its arrangement in the context of the broader landscape and the distance to other habitats are also factors that will influence the type and number of species expected to use a habitat area. The matrix of land use patterns and natural features such as riparian corridors, lakes, and wetlands produces habitat areas which are typically shaped in elongated strips, or patches and clumps of vegetation. Strips of habitat can function as corridors which facilitate the movement of wildlife. Clumps provide larger areas of habitat which buffer wildlife from surrounding developed lands. The distance between habitat areas will determine the likelihood of movement from one area to another. Beyond a certain distance, habitat clumps become isolated islands from which movement is severely restricted. The age of a habitat area and the amount of disturbance to which it has been subjected will also affect its value for wildlife habitat. An older well established habitat area is likely to exhibit greater structural diversity supporting a broader range of wildlife species.

Impacts of Development

Human activity in and near habitat areas impact the viability of the wildlife usage. Impacts associated with human activity which have detrimental cumulative effects on wildlife habitat include trampling of vegetation; noise; use of machinery; traffic; predation by dogs and cats; the use of pesticides, herbicides, and fertilizers; removal of vegetative cover and replacement of vegetation with plant species lacking diversity. Development, including golf courses, has resulted in the fragmentation and in some cases eradication of wildlife habitat.

Fragmentation of wildlife habitat results from the filling of wetlands, relocation of streams and drainages, clearing of forests, and road construction. Large tracts of naturally vegetated areas are broken into smaller patches of habitat. Many problems result from fragmentation. Development can create barriers between remnant patches of habitat, which restricts wildlife movement. Breaking up large clumps of habitat into smaller patches increases the edge condition of that habitat, affects temperature and humidity, and reduces core space. The ratio of edge habitat to interior habitat increases as fragment size decreases. Edges, also known as ecotones, occur where a habitat, such as a wetland, meets a road, a clear-cut, or some other landscape condition, natural or artificial. It is generally believed that edges, overall, are detrimental to the maintenance of species diversity. They can also change microclimatic conditions. Deleterious edge effects can extend into the undisturbed area and include 1) higher frequency and increased severity of fire, 2) higher intensities of predation, 3) higher probability of nest parasitism, and 4) higher intensities of browsing and other forms of disturbance that favor weedy species (Soule, 1991).

Development in riparian corridors can impact fishery resources by reducing habitat due to clearing of vegetation. The absence of shading vegetation along stream banks can cause a significant increase in water temperature. As water temperature reaches into the mid to upper eighties, dissolved oxygen levels decline and many forms of aquatic life enter into a condition of stress. Trout and other salmonids do best when the maximum temperature does not exceed 68 to 72 degrees Farenheit (Klein, 1990). Clearing can also reduce bank stability and the supply of large organic debris to the stream channel, which would degrade fish habitat value.

Large Scale Wildlife Enhancement Planning

The first step of the golf course planner is to conduct a thorough evaluation/survey to identify the type and quantity of wildlife habitat present on the site; King County's draft SEPA wildlife study guidelines should also be reviewed. The survey methodology should be developed in consultation with federal, state and local agencies, and with the assistance of a trained wildlife biologist. Using this site assessment, the course layout should attempt to avoid impacts to valuable habitat areas where possible. Unavoidable impacts should be minimized by choosing alternative design solutions and construction techniques which will have less deleterious effects. Opportunities for enhancement and connecting wetlands and other habitat (on-site and off-site) into a continuous network should also be explored.

If a wildlife habitat enhancement program is proposed as part of a mitigation plan, the planner should begin by targeting the species or wildlife community that will be impacted by the proposed development, and determine the area needed for the species with the largest space requirements. This will establish the core area required for enhancement. The configuration of the existing habitat should be reviewed to identify where the spatial requirements of the targeted species can or cannot be accommodated. The resulting map will reveal where opportunities and constraints for enhancement exist. The evaluation area should consider wildlife protection areas and seek to maintain connections to those areas. The planner can use this map as the basis for planning the mitigation enhancement area and its relationship to other more active programmed course activity.

Several different approaches to enhancement are possible.

- Focusing exclusively on maximizing opportunities for wildlife enhancement, the planner would tend to locate the habitat area in one large clump in the corner of a site (Goldstein, 1982/1983). This would result in the greatest possible separation from human activity, especially vehicular traffic.

- If the planner is interested in including the habitat area as a visual amenity, and wildlife concerns are minimal, the tendency would be to locate the habitat area in the center of the site (Goldstein, 1982/1983). This concept provides the greatest accessibility and maximizes the visual surface area it presents to the surrounding development. This layout concept creates a compromise to wildlife habitat value.

- The greatest compromise occurs if the habitat area is fractured throughout the site in small patches or strips; this should be avoided in sensitive habitat areas (Goldstein, 1982/1983). Strips of vegetation distributed throughout the site have an aggregate visual surface area which is much greater than a single large clump of vegetation located in the center or the corner of the site. However, it is difficult to achieve structural diversity requirements of high value habitat with strip plantings. Strip plantings are most effective when planned as broad corridors to facilitate the movement of wildlife.

- The ideal compromise between visual amenity vs. wildlife value is a mixture of clumps/patches and strips (Goldstein, 1982/1983).

The best way to maintain the value of wildlife habitat is to minimize the golf course's contribution to habitat fragmentation. Among the most important measures that can be taken are the consolidation of open space areas (Soule, 1991). This approach reduces deleterious edge effects. A possible mitigation strategy would be to use strips as connections between clumps to provide corridors and prevent isolation.

Ultimately, the quality of the existing site, its ecological diversity, land use history and vegetation composition (and successional stage) will all influence the wildlife habitat any given site will support. All these factors should be considered when developing an enhancement program.

Site Specific Wildlife Enhancement Planning

The most successful strategies for habitat enhancement are those which make use of the existing habitat to articulate site layout. The following planning approaches are recommended:

- Endeavor to fit the development to the landscape rather than forcing a program onto the site.

- Existing habitat features should be surrounded by a buffer to minimize the impacts of development.

- Locate the least active uses adjacent to buffer area. Plan to locate the most active use areas the greatest distance from the habitat area.

- Individual features of the site which provide habitat value should be incorporated into the overall design of the golf course.

- Mature individuals, groups or "specimen trees", and understory vegetation should be retained when possible.

- Native vegetation within the roughs can provide wildlife habitat. Retain dead trees and snags, downed logs, and brush piles within the rough.

- Carefully select regionally adapted plant species to minimize maintenance requirements.

- Implement an integrated pest management program to minimize the use of fertilizers and pesticides (see Chapter 7).

- Stream channels located on proposed sites should remain in a natural unaltered state.

- Retain native vegetation adjacent to streams to maintain appropriate water temperature and habitat conditions for fisheries (Klein, 1990). (See King County SAO for applicable stream buffer requirements).

The use of plant material adapted to the Pacific Northwest is recommended for landscape development of both natural and active areas in a golf course site plan. The term adapted should not be confused with "endemic". As used in this manual, adapted species are those that will flourish under existing microclimatic conditions for each portion of the site. Adapted plant material requires less maintenance than exotics that may be poorly adapted to local conditions and therefore, need more intensive maintenance. The use of chemicals such as pesticides, herbicides, and fertilizers is minimized. In addition to reducing maintenance requirements, the use of adapted plant material can increase the value of wildlife habitat and bio-diversity, reduce erosion and sedimentation, reduce the need for irrigation, and provide seasonal visual interest.

The WDW has developed a list of plant material that is recommended as providing food for western Washington birds (see Table 4-1 at the end of this section). It should be noted that the plant material recommended provides habitat for insects which can be found in the twigs, bark, and leaves of trees and shrubs. Birds feed on insects, as well as the seeds, nuts, and fruit of the plants listed.

4.2 Wildlife Habitat Management and Maintenance

Introduction

Mitigating impacts of golf courses on wildlife habitat can best be accomplished by incorporating wildlife habitat considerations into the overall planning process, including the design, construction, and operation phases. Goals for habitat management should be established and incorporated into the overall golf course management plan. Depending on management goals, specific wildlife populations can be increased, decreased, or maintained.

In addition, golf course maintenance practices that avoid or minimize impacts should be implemented. Monitoring of maintenance procedures should be an element of the management plan; this can help reduce the risk of cumulative impacts over time via source control. The degree of monitoring should be commensurate with the sensitivity of the site's wildlife and the scale of the management plan.

Use of Chemicals: Pesticides, Insecticides, Herbicides and Fungicides

Replacement of existing vegetation with turfgrass and intensive turfgrass management practices are among the most significant impacts of golf course development (see Chapters 8 and 9). If not properly managed with an integrated pest management plan, these practices can alter the structure and availability of wildlife habitat by affecting the basic habitat requirements: food, water, and cover. Applying insecticides and other chemicals on turfgrass alters the composition of insect populations. Many species rely on insects as a primary food source. Wildlife survival and reproduction corresponds directly to the abundance of food. The reproductive season of many species corresponds to peaks in insect populations. Birds and mammals emigrate from pesticide treated areas due to the reduction in insect populations. This can affect breeding patterns. Birds are affected by changes in territory size and structure, increased risk of predation, increased difficulty in locating and building new nest sites, and increased competition for food. For those species which remain in treated areas, the reduction in the food source could result in reduced survival of offspring. Pesticides create changes in other habitat characteristics. Herbicides and other chemicals change the structure of vegetation. Chemically removed vegetation also reduces the food supply of prey populations (Balogh, 1992).

The Institute of Wildlife and Environmental Toxicology (TIWET) has a multidisciplinary research program under way in Washington State and other states to study the interactions between wildlife and chemicals released into the environment. Requests for relevent local information provided by TIWET should be directed to:

Dr. R. J. Kendall
The Institute of Wildlife and Environmental Toxicology
Clemson University
Pendleton, South Carolina 29670

Wildlife exposure to pesticides can occur in a variety of ways. Routes of exposure include direct consumption of granular formulations or solutions from standing water, ingestion of poisoned insects and other contaminated prey, residues on treated vegetation and seeds, and dermal absorption and inhalation (Balogh, 1992). There are two types of direct effects of pesticides and herbicides on wildlife: acute and chronic. Acute effects are episodic and occur when exposure to large quantities of pesticides trigger an immediate response. For example, acute effects may occur if wildlife is exposed to an application of pesticides immediately followed by a heavy rain. Potentially toxic concentrations of pesticides can exist in runoff or surface pooling of drainage. Toxic concentrations of pesticides can also occur in accidental spills and over-application, or if the pesticides have not been watered in properly. Chronic effects are more subtle than the dramatic impacts of acute exposure. Small doses of a chemical over time may result in chronic toxicity. Chronic exposure to pesticides -- which may be difficult to identify by casual field observation -- can cause reproductive effects, carcinogenicity, bioconcentration, changes on population density, and teratogenesis (Balogh, 1992).

It is difficult to determine the toxicity of any given chemical because of the complex interaction between chemical and environmental variables. The level of toxicity depends on the species exposure to the chemical, levels of concentration, the formulation, timing and duration of precipitation, and amounts of runoff (see Chapter 9). Careful planning -- that accounts for timing and rate of application, supervision of personnel, and proper handling -- will minimize the risk of exposure (see Chapter 8). All chemicals should be applied by a licensed operator according to the manufacturers specifications (Balogh, 1992).

Integrated Pest Management Programs

Integrated pest management (IPM) programs have been successful in reducing the impacts of turfgrass maintenance on wildlife habitat. IPM practices include:

- use of biological controls and turf varieties resistant to disease and pests prior to chemical treatment;
- development of economic thresholds and scouting for pests and diseases prior to chemical treatment;
- reduction of chemical loading of golf courses by avoiding routine treatment whenever possible; and
- incorporation of wildlife species onto the pest control plan such as bats and insect eating birds (Balogh, 1992).

See Section 8.3 for additional discussion of Integrated Pest Management.

Impacts of Construction and Maintenance

Several impacts to wildlife habitat are associated with golf course construction and maintenance. Heavy construction machinery generating noise and compacting soils, site clearing and grading operations, and alteration to drainage patterns can change habitat and eliminate sources for food, water, and cover required by wildlife. Some of the most common impacts of golf course construction and maintenance practices include (Balogh, 1992):

- Stream channelization,
- Loss or permanent destruction of wetlands,
- Loss of wooded zones on waterways,
- Increased temperature of streams and lakes as a result of shade reduction, reduction of interflow, release of heated water from shallow ponds, and release of heated storm flow from impervious surfaces,
- Reduction of stream base flow resulting from irrigation withdrawal,
- Pollution of surface water and groundwater resulting from nonpoint movement of pesticides and fertilizers,
- Pollution of surface and ground waters from periodic spills of pesticides, fertilizer, and fuels,
- Movement of pollutants in storm flow from impervious surfaces,
- Acceleration of channel scouring due to increased duration and/or velocity of storm water runoff,
- Altering the frequency and magnitude of flooding in surrounding terrestrial and aquatic systems, and
- Erosion or soil compaction during construction..

To minimize impacts to wildlife habitat resulting from construction and maintenance, select sites for development that are minimally constrained by sensitive areas, follow standard practices for temporary sedimentation and erosion control, maintain adequate buffers (reflective of wildlife objectives) around sensitive areas, and develop irrigation and water management practices that minimize withdrawals and do not increase water temperature.

Thinning Buffers and Wetlands for Golf Play

The thinning of wetland and buffer vegetation to facilitate course play is not permitted by King County SAO regulations. However, a variance from this limitation may be granted if an analysis of alternatives determines that course layout cannot be achieved without selective thinning. The potential impacts of thinning must be evaluated by the applicant. A mitigation plan must also be developed to compensate for any resulting loss of wetland or buffer functions.

When a line of play through wetlands/buffers cannot be avoided, the golf course planner should locate fairways to minimize potential impacts. Narrow areas within wetlands, which have already been disturbed or where the height of vegetation will pose the least impediment to play should be identified. Additional mitigation measures that should be considered include the following:

- limit thinning to a minimum corridor:
- locate haul roads (e.g. for hauling debris) to minimize vegetation disturbance;

- create habitat features in other parts of the buffer through use downed logs and brush;
- consult with a wildlife biologist to determine appropriate locations for habitat features;
- plan thinning to avoid disruption to wetland hydrology; and
- use hand rather than chemical means to accomplish thinning.

Wildlife Management/Maintenance Policies

Establishing goals is the most important initial activity in developing a habitat management program. The overall goal of habitat management should be to sustain wildlife habitat throughout course construction, establishment, and maintenance. Steps and factors to be considered in establishing management goals include the following:

- Determine the species to be favored in the management plan. The selection of species may be based on legislative mandate, species needed for pest control, or species which meet other habitat goals related to maintenance of the course.

- Determine the habitat requirements for territory size, foraging, breeding, nesting, for each species. Various animal species have habitat needs related to the successional stage, amount of canopy closure, vegetation height, vegetation diversity, the presence of snags and decaying logs, and other physical characteristics of the plant community. These species specific dependencies on habitat features must be considered.

- Once the habitat requirements for the targeted species is determined, establish overall goals for the wildlife management program. An example of a goal may be to restore breeding population of an insect eating species to assist with pest control.

- Determine the habitat structure required by the targeted species. Then develop a restoration plan to install the vegetation and special features needed to restore the desired habitat.

- Once installation is complete, a monitoring program should be developed to measure the success of the wildlife management plan.

Specific Management Practices

The Washington Department of Wildlife (WDW) has developed a list of recommended wildlife habitat management practices. These recommendations are listed below (WDW, undated). In addition, the United States Golf Association/Audubon Cooperative Sanctuary Program for Golf Courses can provide information on techniques for enhancing wildlife habitat during golf course development. (Contact Seattle Audubon Society, 8028 35th Avenue N.E., Seattle, WA 98115).

Primary Priority Habitat and Species (PHS) Management Practices

1) Permanent protected area: an area around the nest site of the PHS species. No permanent land use change should be allowed within the protected area.
2) Conditioned Area: establish a buffer around the habitat or important habitat component of the PHS species within which land use changes are restricted or conditioned.
3) Natural habitat: Maintain a natural habitat providing a suitable combination of food, water, and shelter relatively free of human disturbance.
4) Selective clearing: Limit clearing.
5) Maintain a particular successional stand, plant community, or plant species.
6) Create or maintain snags; cavity-nesting birds use this as their primary habitat.
7) Maintain structural integrity of wetlands
8) Maintain structural integrity of riparian areas

Secondary PHS Management Practices

9) Limit human disturbance
10) Retain downed logs/stumps
11) Allow natural regeneration of logged/burned areas
12) Maintain water flow and water quality, control stormwater runoff
13) Limit in-stream structures, such as bridges, piers, boat ramps, or culverts which impede the animal's natural movements
14) Limit the amount of roadway and /or restrict their placement in the landscape.
15) Limit chemical applications including insecticides, herbicides, rodenticides, and pesticides
16) Limit non-native and/or introduced animals that may act as competitors or predators
17) Limit scientific collecting
18) Limit wire fences to allow free movement of animals
19) Provide artificial nest sites or nest boxes

Monitoring

Monitoring provides a framework to evaluate the progress of wildlife enhancement and maintenance measures over time. Problems can be identified and modifications made to enhance the success of the project. The most effective and least expensive way of judging the effect of a golf course upon the environment is biological monitoring. (Klein, 1990) Studying changes in fish, insect, and algae populations associated with waterways present on a golf course can detect and identify the impacts of human activity on the aquatic environment. Techniques for monitoring the health of fresh and free flowing waters are described in "Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish", available from the U.S. Environmental Protection Agency, Assessment & Watershed Protection Division, 401 M Street, S.W. Washington, D.C. 20460 (use order number EPA 444/4-89-001) (Klein, 1990). Monitoring protocols are also described in the Guide for Wetland Mitigation Project Monitoring, Horner and Raedeke, Washington State Department of Transportation, 1989, and the Ohio EPA "Index of Biotic Integrity".

Examples of data to establish a baseline of data for monitoring habitat should include: field surveys or information about on-site conditions prior to construction; data collected in the first year following implementation; information from a reference site or from literature describing similar situations; and information from studies of existing, undisturbed habitat (Stevens, 1992). At a minimum, monitoring should be conducted to evaluate progress relative to the goals and performance standards established at the beginning of each project. A detailed discussion of designing a monitoring program can be found in Washington Department of Ecology's Restoring Freshwater Wetlands in the Pacific Northwest (Stevens, 1992).

Methods of monitoring the potential effects of changes in water quality on aquatic resources include monitoring drainage pond water quality and biomonitoring. Sediments and fish tissue from the pond will provide the most reliable medium for detecting pesticide residues. The concentration of a particular pesticide in sediment or fat might be 10, 100 or 1,000 times greater compared to water (Klein, 1990).

Biomonitoring techniques for assessing changes in water quality have been developed by the U.S. Environmental Protection Agency (EPA). These relatively inexpensive techniques can determine the pesticide level in water that will threaten aquatic species. Biomonitoring techniques can also determine the cumulative effects of all pesticides that affect aquatic resources, important for assessing the toxicity of a combination of pesticides. More information of biomonitoring techniques can be found in *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms*, EPA, 600/4-87/028, and *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*, EPA, 600/4-87/001.

4.3 Buffers

Introduction

Buffers act as undeveloped transitional zones between environmentally sensitive areas and developed lands. The buffer zone functions to protect sensitive habitat areas -- such as wetlands, riparian corridors, shorelines, and steep slopes -- from impacts of development. The most damaging impacts of golf course development on wildlife habitat include construction activities, increased runoff and decreased water quality. (Note: According to King County regulations, natural water bodies and artificial water bodies created as mitigation are required to designate buffers. Buffers do not apply to artificially created water facilities designed for stormwater management, irrigation reservoirs, or aesthetic purposes).

Buffer Functions

Wildlife habitat is composed of a habitat feature such as a wetland or riparian corridor plus the adjacent upland surrounding that feature. Many wetland dependent species, for example, need both wetland and adjacent upland to satisfy their basic survival needs: food, water, shelter from climatic extremes, vegetative structure, and cover for reproduction and rearing of young (WDW, 1991).

Wetland buffers, for example, can function to maintain water quality and quantity, maintain fish and wildlife habitat, and minimize disturbance from human activity. Buffer vegetation can help keep water and surface temperatures cooler in the summer and warmer in the winter; provide food and cover for wildlife (ranging from small to large mammals); function as rearing areas for the young; and satisfy nutrient and cover requirements of aquatic systems and their organisms. Large organic debris is generally believed to be essential habitat requirement of native fish populations. Downed logs in stream channels help develop pools and fish hiding cover. Smaller organic debris such as leaf litter, twigs, and other plant parts provide an extremely important food source for aquatic ecosystems. Buffers function to filter sediments and pollutants. Dense vegetation growing along stream channels serve to slow floodwater velocities, decreasing flood related erosion and other damage.

The transitional zone between upland and aquatic habitat provides habitat for many wildlife species. Fifty vertebrate species use the water/shrub edge for primary breeding and feeding, forty-six use the water/forest edge, ninety-eight use the riparian zone of herbaceous wetlands, and eighty-five use open water ponds (Washington Department of Wildlife, 1991).

Buffer Needs of Fish and Wildlife

Buffers vary in size and structure according to the sensitivity of the habitat area the buffer protects. Buffer width may be determined by legislative mandate, or by the habitat requirements of the species or ecosystem targeted for protection. Buffer requirements also vary according to the level of activity occurring nearby. The WDW has made buffer width recommendations to meet the needs of fish and wildlife. King County typically determines required buffers for wildlife habitat during project review. Minimum buffers for streams and wetlands are established in the SAO (see Table 4-2).

Wetland systems that have an open water component, or are heavily used by migratory birds, require larger upland buffers. Depending on the species present, highly rated wetlands with important wildlife functions may require buffers of 300-600 feet when located adjacent to a high activity land use (WDW, 1991). These buffers may be reduced to 200 feet when the wetland is adjacent to a lower intensity land use. In all cases, wildlife management objectives should be consistent with buffers; in specific situations, this may result in buffers greater than minimum required widths.

Sensitive Areas Ordinance Buffer Requirements

The King County SAO (Ordinance No. 9614) defines buffers in the following manner.

> *"Buffer means a designated area adjacent to and a part of a steep slope or landslide hazard area which protects slope stability, attenuation of surface water flows and landslide hazards reasonably to minimize risk; or a designated area adjacent to and part of a stream or wetland that is an integral part of the stream or wetland ecosystem."*

King County's minimum buffer requirements are shown in Table 4-2.

Note on Control of Turf-Attracted Species

Canada Geese (*Branta canadensis*) can become a nuisance to golf courses when they forage in large numbers and litter open turf with feces. A wildlife biologist should be consulted for managing any problems that develop with this species.

4.4 Areas Requiring Additional Research

Evaluation of risks associated with agrochemical impacts on wildlife will involve a research program including laboratory and field studies in the disciplines of analytical toxicology, biochemical toxicology, wildlife ecotoxicology and wildlife ecology (Kendall and Ackerman, 1992). As such research programs occur, their results should be used to update this manual.

Table 4-1. Plants for Wildlife in Western Washington

NAME	MAX. HEIGHT	SUN	WATER	NUMBER OF BIRD SPECIES ENHANCED	NOTES
CONIFEROUS TREES Note: Although some coniferous trees do not offer abundant seeds, many provide excellent cover and insects for a variety of wildlife.					
Silver Fir *Abies amabilis*	>60'	2 - 3	2	6	Spirelike crown is attractive. Slower growing in shade, and may not exceed 60 feet at lower elevations. Cones on all firs stand upright on branch; seeds are eaten by wildlife; large seed crops are produced every 2 - 3 years.
White Fir *Abies concolor*	>60'	2	2	6	Can survive in very poor soils. Slow growth when young. Cool, deep, moist soils are best.
Grand Fir *Abies grandis*	>60'	2 - 3	2	6	Needles are two-ranked (in one plane). Best in deep, moist alluvial soils.
Subalpine Fir *Abies lasiocarpa*	>60'	2	2	6	Spirelike crown. Cool, moist soils are best. Slow growing.
Nobel Fir *Abies procera*	>60'	2	2	6	Seeds not abundant and produced irregularly. Relatively rapid growth. Full sun with cool, deep, moist soil is best.
Alaska Yellow Cedar *Chamaecyparis nootkatensis*	>60'	2	2	11	Has drooping branches and pendulous foliage. Does not thrive in cold dry winds or high summer heat. Birds eat 1/4" seeds from small, round cones. Large seed crops are irregularly produced.
Western Larch *Larix occidentalis*	>60'	1	2	7	Needles are dropped each winter - attractive fall foliage. Only one typical urban bird species eats the seeds, which grow in small, 3/4" cones. Native to eastern Washington.
Engelmann Spruce *Picea engelmannii*	>60'	2	2	13	Best in deep, rich, loamy, moist soil. Wildlife eats 1/8" seeds in 1" -2" cones. Large seed crops produced every 3-6 years.
Sitka Spruce *Picea sitchensis*	>60'	2	1 - 2	13	Does best in foggy, moist atmosphere. Very important coastal tree, especially on Olympic Peninsula. Wildlife eats 1/8" seeds in 2" -4" cones that drop in late fall. Fast-growing, needs large area.

Sun Codes: 1 = full sun only
2 = full sun to part shade
[illegible]

Water codes: 1 = ample
2 = moderate
3 [illegible]; dr[illegible] t tol[illegible]

NAME	MAX. HEIGHT	SUN	WATER	NUMBER OF BIRD SPECIES ENHANCED	NOTES
Red Alder *Alnus rubra*	>60'	1	1 - 2	6	Tolerates brackish soil. Good for restoration of disturbed sites; adds nitrogen to soil. Common native tree. Mountain or Sitka alder *(Alnus sinuata)* is smaller, usually forming shrubby thickets at higher elevations, but may be hard to find commercially. Birds eat the very small seeds in the 3/4" round "cones" of alders.
Paper Birch *Betula papyrifera*	>60'	1	2	12	Hardy, fast growing. Smooth white bark (on older trees) is very attractive. Good fall color. Seed especially valued by goldfinches, siskins, juncos. Less common commercially but should be more preferred than European birch.
Western Dogwood *Cornus nuttallii*	30-60'	3	2 - 3	25	Intolerant of frequent watering & fertilizing. Protect young bark fron sun and mechanical damage. Effective against background of darker conifers. Flowers in spring and again in late summer. Wildlife eats fruit clusters.
Oregon Ash *Fraxinus latifolia*	40-80'	2	1	5	Dioecious; female trees produce winged seeds. Good for revegetation of wet, low-lying areas; will grow in standing water in winter. May be hard to find in nurseries.
Quaking Aspen *Populus tremuloides*	20-40'	2	2	--	Offers cover but no seeds that can be eaten by wildlife. Flattened leaf stalk allows leaf to quiver in wind. Grows in many soil types. Forms sucker shoots. Invasive roots; don't plant near sewer lines.
Black Cottonwood *Populus trichocarpa*	>60'	1	1	--	Massive, fast-growing, good for reclamation of wet sites. Offers cover and nesting, but seeds not suitable for most wildlife.
Bitter Cherry *Prunus emarginata*	30-50'	2	2	28	Many other non-native varieties available, usually smaller in stature. Avoid sterile types that don't produce fruit.
Oregon White Oak *Quercus garryana*	>60'	1	2 - 3	17	Also known as garry oak or Oregon post oak. Drier gravelly soils are best. This species is one of the best oaks for the Pacific Northwest.
Cascara Buckthorn *Rhamnus purshiana*	30-40'	2	2	13	Also known as bitter-bark. Grows in a variety of soils; moist is best. Does not do well in highly urbanized areas. Wildlife eats the round, bluish-black fruit.
Willow *Salix* spp.	variable	1	1	--	Many species from small shrubs to medium trees. Provides cover and insects but no seeds or fruit that can be used by wildlife. Good for reclaiming wet sites - ponds, streams, wetlands. Roots invasive; don't plant near sewer, septic, or irrigation lines.

Sun Codes:
1 = full sun only
2 = full sun to part shade
3 = part shade only
4 = deep shade

Water codes:
1 = ample
2 = moderate
3 = little; drought tolerant

NAME	MAX. HEIGHT	SUN	WATER	NUMBER OF BIRD SPECIES ENHANCED	NOTES
Shore Pine *Pinus contorta contorta*	15-30'	1	1 - 2 - 3	17	Short, contorted trunk and dense, irregular crown. Tolerant of soil conditions. Serotinous cones (open only after exposure to fire), so wildlife value is reduced.
Lodgepole Pine *Pinus contota latifolia*	>60'	1	2	19	Tolerates many soil conditions; does best in moist, well-drained, sandy or gravelly loam. Serotinous cones may remain closed 15-20 years, so wildlife value is reduced.
Western White Pine *Pinus monticola*	>60'	1	2	21	Best in large landscape settings. 1/3" seeds with 1" wings are in 8"-11" cones. Good root system makes it especially wind-firm. Susceptible to white pine blister rust. Eastern white pine (Pinus strobus) of eastern U.S. is similar, but cone is smaller (4"-8").
Douglas-fir *Pseudotsuga menziesti*	>60'	2	2	2	Most important of our native conifers in western Washington. Fast growing. Wildlife eats 1/4" seeds in 2"-4" cones; heaviest cone crops occur every 5-7 years. Provides shelter, nest sites, insects.
Western Yew *Taxus brevifolia*	15-30'	2	2	4	Grows as a shrub or small tree. Wildlife eats seeds and scarlet, berrylike cup (aril). Dioecious - only female plants produce seeds. May be hard to find in plant nurseries.
Western Red Cedar *Thuja plicata*	>60'	2	1 - 2	5	Important Pacific Northwest species. Generally found in moist flats and slopes, and along water margins. Shade tolerant; attractive bark. Foliage sprays are drooping, often fernlike. Wildlife eats the small (1/8") seeds in 1/3" - 1/2" cones.
Mountain Hemlock *Tsuga mertensiana*	>60'	2	1 - 2'	7	Excellent for natural landscapes. Slow growth, choice form. Best in groups of 3-5 of differing heights. Blends well with salal and huckleberry. Cool, moist soil is best. Wildlife eats the very small (1/16") seeds from the 1/2" - 3/4" cones.
Western Hemlock *Tsuga heterophylla*	>60'	2	2	7	Graceful, pyramidal tree. Protect from drying wind and sun. Faster growth and larger size than the Mountain Hemlock.
Vine Maple *Acer Circinatum*	15-30'	2	1 - 2	8	Large shrub to small tree; often multi-stemmed. Best suited to woodland plantings with ferns and conifers. Excellent fall color. All maples produce winged seeds that are eaten by wildlife.
Bigleaf Maple *Acer macrophyllum*	>60'	1	1 - 2	9	Best suited for large plantings. Stumps will produce sprouts resulting in a dense mass of stems. Fast growing.

Sun Codes:
1 = full sun only
2 = full sun to part shade
3 = part shade only
4 = deep shade

Water codes:
1 = ample
2 = moderate
3 = little; drought tolerant

NAME	MAX. HEIGHT	SUN	WATER	NUMBER OF BIRD SPECIES ENHANCED	NOTES
BROADLEAVED EVERGREEN TREES					
Pacific Madrone *Arbutus menziesii*	>60'	2	2 - 3	3	Choice form, especially against an ocean view. Constant litter from peeling bark and leaves can be a problem. Wildlife eat the flowers and orange-red, berrylike fruit.
DECIDUOUS SHRUBS AND GROUNDCOVER					
Saskatoon Serviceberry *Ameanchier alnifolia*	3-8'	2	2	21	Brief but showy spring flowers, excellent fall color. Best in woodland edge, along water edge, or in a shrub border. Wildlife eat the pea-sized, purple-black fruits in fall. Other serviceberries are available.
Scrub Birch, Bog Birch *Betula glandulosa*	6-15'	1	1	9	Found in wetlands of the Pacific Northwest. Wildlife eat the small seeds in woody "cones".
Bunchberry Cornus canadensis	<1'	3 - 4	1 - 2	18	Deciduous groundcover with attractive white "flowers". Rich, moist, acid soil needed. Will spread. Wildlife eat the red berries in autumn.
Red Osier Dogwood *Cornus stolonifera*	6-16'	1	1 - 2	24	Also called creek dogwood. Valuable for habitat reclamation, especially in moist areas. Multi-stemmed red branches are attractive all year; red autumn foliage. Wildlife eat the white to bluish berries.
Trumpet Honeysuckle *Lonicera ciliosa*	—	1	2	15	Groundcover or climbing vine. Has tubular red flowers in clusters used by hummingbirds. Wildlife eat the reddish-orange fruit in autumn. Other honeysuckles are available in nurseries.
Twinberry *Lonicera involucrata*	6-15'	1	2	15	Found in moist areas of the Pacific Northwest. Dense foliage. Yellow twin flowers. Wildlife eats the purplish-black fruits.
Indian Plum, Oso Berry *Osmaronia cerasiformis*	6-15'	2	2	6	Good for woodland settings native plantings in open spaces. Produces showy white flowers in early spring. Dioecious; only female plants produce the olive-sized bluish-black berries eaten by wildlife.
Smooth Sumac *Rhus glabra*	6-15'	1	3	20	Spreads by shallow roots. Good fall color. Clusters of seeds stay long on plant, not highly valued by wildlife.

Sun Codes: 1 = full sun only
2 = full sun to part shade
3 = part shade only
4 = deep shade

Water codes: 1 = ample
2 = moderate
3 = little; drought tolerant

NAME	MAX. HEIGHT	SUN	WATER	NUMBER OF BIRD SPECIES ENHANCED	NOTES
Red-flowering Currant *Ribes sanguineum*	6-10'	2	2	10	Spring flowers are attractive to hummingbirds. Wildlife eat the round, blue-black berries. Several other species available.
Wild Rose *Rosa* spp.	3-8'	2	2 - 3	12	Several species and varieties available, both native and introduced. Nootka, multiflora, and rugosa roses are most common. Wildlife eat hips that are persistent into winter.
Thimbleberry *Rubus parviflorus*	3-6'	2	1 - 2	25	Unkept appearance is best in wild landscaping. Large white flowers. Wildlife eat the mealy fruit.
Creeping Raspberry *Rubus pedatus*	<1'	3	2	20	Also known as strawberry bramble. Good groundcover in shaded, natural landscape. Bright red berries eaten by wildlife. The trailing blackberry *(Rubus ursinus)* is similar but with a thicker, more thorny vine; dioecious; common in logged/burned areas.
Salmonberry *Rubus spectabilis*	6-15'	2	1 - 2	25	Reddish-purple flowers attract both bees and hummingbirds; wildlife eat the red fruits.
Red Elderberry *Sambucus racemosa*	6-15'	1	1 - 2	29	Prune to avoid leggy apearance. Best in natural garden. Blue elderberry *(Sambucus cerulea)* is similar, but best in eastern Washington. Raw berries may be toxic to humans.
Sitka Mountain Ash *Sorbus sitchensis*	3-10'	1	2	7	Usually found at higher elevations in avalanche thickets or in understory. Large clusters of reddish-orange fruit eaten by wildlife. Good fall color.
Snowberry *Symphoricarpos albus*	3-6'	2	2	10	Will spread to form a thicket that provides good shelter. White fruit persists into winter, although it is not highly valued.
Red Huckleberry *Vaccinium parvifolium*	6-15'	3	1 - 2	13	Best in moist, coniferous woodland setting. Often grows on top of tree stumps. Has bright, red, semi-translucent berries.
High-bush Cranberry *Viburnum opulus*	6-15'	2	2	11	Fruit stays on plant into winter but is not highly valued by wildlife. Other non-native viburnums are common in nurseries; some do not bear fruit; none have highly valued fruit.
Tall Oregon Grape *Berberis (Mvahonia) aquifolium*	5-10'	2 - 4	2 - 3	6	Useful in woodland settings because of spiny leaves, berry clusters. Yellow flower clusters and bronze color of new leaves are attractive. Blue-black fruit are not readily consumed by birds. Cascade Oregon grape *(Berberis nervosa)* is similar but seldom exceeds 2 feet.

Sun Codes:
1 = full sun only
2 = full sun to part shade
3 = part shade only.
4 = deep shade

Water codes:
1 = ample
2 = moderate
3 = little; drought tolerant

NAME	MAX. HEIGHT	SUN	WATER	NUMBER OF BIRD SPECIES ENHANCED	NOTES
Salal *Gaultheria shallon*	3-8'	2	2	2	Fruit not readily consumed, but provides good cover. Small, pink urn-shaped flowers are attractive. Lower growing in full sun. Best in native landscape in massed plantings.
Evergreen Huckleberry *Vaccinium ovatum*	6-15'	2	2	13	Does best in part shade, open woods; grows large and leggy in deep shade. Attractions are new bronze foliage, pink flowers, abundant fruit.

Sun Codes: 1 = full sun only
2 = full sun to part shade
3 = part shade only
4 = deep shade

Water codes: 1 = ample
2 = moderate
3 = little; drought tolerant

Table 4-2. Minimum Buffer Widths King County Sensitive Areas Ordinance

Resource	Class I	Class II	Class III	Slope >40%
Wetlands[1]	100	50	25	
Streams[2]	100	50-100[3]	25	
Slopes[4]				50

Notes:

1 These buffer widths may be adjusted as required to account for critical drainages, location of hazardous materials, critical fish and wildlife habitat, landslide or erosion hazards, ground water recharge or discharge, or the location of trail or utility corridors.

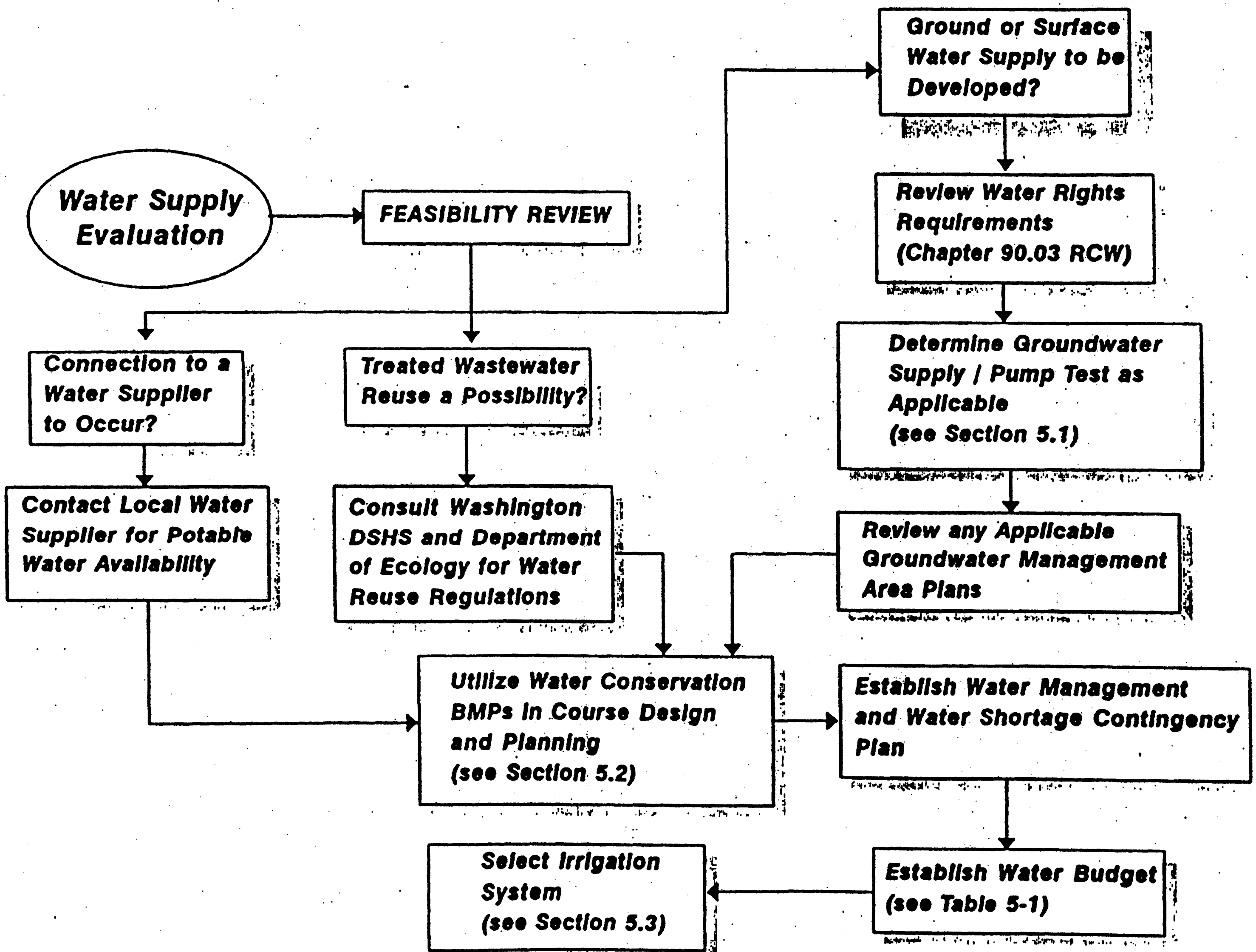
2 Buffers are measured form the ordinary high water mark, or the top of bank. For a description of stream class ratings refer to the King County Sensitive Areas Ordinance (1990).

3 100 feet required for Class 2 streams used by salmonids, 50 feet required for all other Class 2 streams.

4 A minimum buffer of 50 feet shall be established from the top, toe, and along all sides of slopes 40 % or steeper. Native vegetation must be retained within the required buffer area.

Source: King County SAO, 1990.

CHAPTER 5 FLOWCHART - *Water Consumption & Conservation*



Water Consumption and Conservation

Summary of Best Management Practices

- If the anticipated water source for the course is a public water utility, consult with the local water utilities early in the golf course planning process.

- Prepare a water budget based on an end-use analysis that considers water demand of landscape plantings; annual average and summer water use; water needs for establishment period versus ongoing irrigation needs; and all other project water needs.

- Develop a water management plan during golf course design.

- Evaluate availability of groundwater and potential for water reuse.

- Evaluate the applicability of course design that reduces the irrigated turf area.

- Install a centrally controlled irrigation system that establishes the need for water, based on evapotranspiration from a weather station, soil moisture content as indicated by soil sensors, or other means. A properly designed, installed and maintained system will increase the efficiency of water use and promote healthy, disease and pest-resistant turf, which is an important facet of a successful IPM program.

- The irrigation system should be designed by a qualified irrigation designer, reviewed by an irrigation auditor prior to acceptance, and audited annually by trained golf course staff to ensure the system is operating properly.

5.0 Water Consumption and Conservation

A major concern of new golf course siting and design is the water requirement for irrigation of the course. Golf course operation requires management of tees and greens, and to a lesser extent, fairways and rough. In addition, some degree of landscaping using ornamental or adapted species is usually associated with a course. Generally, management of the course involves irrigating during the summer months, with little or no irrigation required during the wet fall and winter months.

This section discusses considerations that need to be evaluated when defining a source for irrigation water. In addition, the section presents various approaches that can be taken during both the planning and management of golf courses to maximize water conservation. A summary of golf course irrigation systems and their effectiveness in water conservation is also provided.

5.1 Water Supply

A prime cultural practice related to turfgrass maintenance is irrigation. There are several potential sources of water, which may include any combination of groundwater, surface water, treated wastewater (reference Section 5.2) or water from a local water supplier. The appropriate source for a given project will be dependent upon several factors after establishing the average and peak irrigation requirements. For surface and groundwater sources these factors include water rights applications and permitting policies and regulations, basin or groundwater management plans involving the proposed source, sustainable yield, and proximity and sensitivity of aquatic habitats or resources that may be affected by the withdrawal. For water reuse, factors include the volume of treated wastewater that will be generated, the quality of the treated wastewater, permitting for the application of treated wastewater under joint Washington Departments of Ecology and Social and Human Services authority, and proximity of a treated wastewater source. For connection to a local water supplier's potable drinking water system, important factors will include capacity and planning by the supplier and guarantees, or lack thereof, to which the water supplier will agree (i.e., irrigation use will more likely have a lower priority for supply than potable uses during any water shortages that occur).

The selected source must have sufficient capacity to sustain the peak irrigation demands with high quality water throughout the lifetime of the course. Otherwise the turfgrass investment is jeopardized. Use rates may vary considerably depending on location and local climate, soil type, turf type, and level of intensity of cultural manipulations such as mowing and fertilization. Generally, all cool season grasses require a replacement of 50% or more of measured evapotranspiration (water lost from plant transpiration and evaporation) to avoid quality declines (see the Water Budget example; Section 5.2, Water Conservation).

Groundwater

Concerns about the use of groundwater for irrigation purposes generally relate to the potential effect of the groundwater withdrawal on nearby wells that may be water sources for individuals or communities. Prior to identifying a potential water source, applicable public water supply plans and regulations should be reviewed. In addition, the following guidelines should be used when identifying a source for irrigation water.

- It should be determined whether the area is located in a Groundwater Management Area (GWMA), as designated by the Department of Ecology. If the area is within a GWMA, the Groundwater Management Plan for the area should be thoroughly reviewed and relevant restrictions and management guidelines identified.

- The groundwater source should only include water from confined aquifer systems, unless an established water right already exists (Draft Hydraulic Continuity Policy, July 6, 1992, Washington State Department of Ecology).

- All well construction should follow Washington State Department of Ecology guidelines (Klein, 1990) and water rights application procedures must be followed through Ecology. A thorough 24-hour pump test must be conducted by a qualified hydrogeologist prior to the onset of groundwater use to assess the potential impact upon other well users in the area, and to indicate the potential for negative impact to resources reliant on groundwater recharge. The test should be conducted at the maximum projected pumping rate. The results of the test should be used to project the cone-of-depression under drought conditions. If the cone-of-depression for production wells would adversely affect existing wells, then alternative water sources must be provided for irrigation and/or other groundwater users.

Treated Wastewater Reuse

Many developments in other states use treated wastewater for irrigation purposes. The use of this water source for irrigation often corresponds with wastewater treatment plant disposal needs. Treated effluent water can be an excellent source for irrigation provided that the level of treatment is sufficient, the nutrient load is acceptable, and that there are no residual industrial contaminants. Additionally, the water needs to be free from abrasives to help reduce damage to the internal components of the irrigation hardware. In Washington State, there are water quality treatment requirements for water reuse on golf courses (see Section 5.2, Water Conservation).

In an agronomic sense, water of good quality would be most desirable for irrigating turfgrass. Quality of irrigation water is described through the concentration of nutrients such as nitrogen and phosphorus, the relative concentration of sodium versus calcium and magnesium, salinity characteristics, the presence of particulates including organic matter, and industrial contaminants. Prior to considering any source for irrigation, its quality for agronomic purposes should be documented via scientific analysis. Concerns for salt buildup may exist and should be addressed in the Golf Course Management Plan.

5.2 Water Conservation

Specialized course design and management techniques should be employed on a site-specific basis to minimize consumption of treated drinking water or withdrawal of water from aquifers for irrigation purposes. Techniques employed in designing and operating water-conserving golf courses include proper turfgrass preparation and culture techniques (see Chapter 8); use of grass species with lower-water demand; use of slow release nitrogen fertilizers; reduced golf course irrigated area; use of adapted or low-water demand vegetation for non-turf areas; use of technically modern and efficient irrigation systems; and water reuse.

Significant differences in irrigation requirements can occur between a 'conventional course' and a water sensitive course. The site-specific impact of water conservation measures should be assessed by development of a water budget (see technical example in Table 5-1). A water budget is a projection of the amount of water that will be used by the golf course. The water budget should be developed based on the amount of area that will be planted, and the water requirements of planting materials to be used (this should be based on evapotranspiration data, if available). While turfgrass is a relatively high water user (specific evapotranspiration estimates are included in Table 5-2) other plantings may require only moderate or no supplemental irrigation after they are established.

Ideally, the water budget for the entire development would also include uses other than irrigation (i.e., indoor plumbing). However, course design and layout present the most significant opportunity for decreasing water use without affecting the aesthetic or play quality of the course.

Table 5–1. Example of a golf course preliminary water budget, showing average monthly water budgets.

Simulation Parameters

No reclaimed water use

Assumed reservoir size in acres: 5

Rainfall data source: Puyallup Station; National Weather Service; total average annual precipitation equals 40.53

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
INPUTS												
Normal Water Supply Rate Desired (gpm) =	226.00											
Water reuse input (Monthly; gpm) =	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainfall (Monthly, in inches)	6.82	4.41	3.74	2.75	1.86	1.67	0.78	1.16	1.92	3.68	5.71	6.03
LOSSES												
Irrigation requirements (Monthly; inches/acre)*	0.00	0.00	0.00	0.00	1.52	2.07	3.92	2.80	0.83	0.00	0.00	0.00
Acres to irrigate	160											
Evapotranspiration (Monthly; inches; assume 0.75 pan–to–lake coefficient)**	--	--	--	1.78	3.38	3.74	4.70	3.96	2.75	0.93	--	--
Conversion Factor Above to Reservoir Evaporation if applicable	0.90											
Assumed other losses (gpm) =	0.00											

* *Calculated as 80% Evapotranspiration, with 80% irrigation efficency, supplement to rainfall*
Irrigation is averaged requirement for tees, greens, fairways & rough in proportion of their respective areas.

** *No evapotranspiration data available for November through March; calculated as zero since rainfall exceeds irrigation demand.*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days in month:	31	28	31	30	31	30	31	31	30	31	30	31
In gallons per minute:												
TOTAL INPUT LESS WATER SUPPLY	20.72	14.83	11.36	8.63	5.65	5.24	2.37	3.52	6.03	11.18	17.92	18.32
TOTAL LOSSES FROM RESERVOIRS	0.00	0.00	0.00	−5.03	−156.99	−218.49	−393.89	−283.00	−91.14	−2.54	0.00	0.00
TOTAL INPUT–LOSSES	20.72	14.83	11.36	3.60	−151.34	−213.24	−391.52	−279.47	−85.11	8.64	17.92	18.32
NET LOSS OR GAIN (w/ up to 226 gpm supply)	20.72	14.83	11.36	3.60	0.00	0.00	−165.52	−53.47	0.00	8.64	17.92	18.32
In gallons per minute:												
WATER SUPPLY REQUIREMENT (with no reservoir elevation change)	0	0	0	0	151	213	392	279	85	0	0	0

Use of Lower Water Demand Grasses (15 to 20% reduction in irrigation demand)

Typical water demand for grasses adapted to western Washington are provided in Table 5-2, below.

Table 5-2. Water Use Rates And Recovery Characteristics Of Turfgrass Adapted To Western Washington

Relative Ranking	Et Rate (Inches/day July 1-Sept. 1)	Turfgrass Species	Deficit Irrig. Requirement (c/c)	Drought Injury Rating
Medium	.08-.15	Hard Fescue	00-50[1]	Very low
Medium	.11-.18	Chewings Fescue	00-60[1]	Low
Medium	.11-.18	Creeping Fescue	00-60[1]	Low
High	.14-.23	Perennial Ryegrass	60-80[2]	Med/High
High	.12-.23	Colonial Bentgrass	40-80[3]	Med/Low
High	.12-.23	Kentucky Bluegrass	60-80[3]	Medium
Very High	.15-.26	Annual Bluegrass	90-100[5]	Very High
Very High	.15-.26	Tall Fescue	20-80[6]	Low

1. Will turn brown when deficit irrigated, but will come back in following spring; however, these do not withstand or recover quickly from wear when stressed.
2. Does not persist below 60% in uniform stands on shallow soils. Related to fertility levels.
3. Recovers well.
4. Doesn't persist below 60%.
5. Not very persistent, although this winter annual will seed prolifically and germinate early. Does not withstand wear but may recover quickly by reseeding.
6. This is potentially very persistent, although research is still underway; the dwarf varieties of this type appear to be preferable.

Source: Water Conservation Coalition of Puget Sound.

As indicated, grasses that require less supplemental irrigation include:

- Creeping Bentgrass (*Agrostis palustris*) - best suited for greens and tees (varieties include Putter, SR-1020, Providence, Penncross, Pennlinks, Cobra and Pro/cup);

- Colonial Bentgrass (*Agrostis tenuis*) - best suited for fairways, tees and selected roughs with selected varieties (varieties include Tracenta, Bardot, Highland and Astoria). (Note: Creeping bentgrass varieties have generally not been recommended for fairway use in western Washington because of their potential aggressiveness and thatchiness. However, newer varieties, such as Egmont, may be useful in the future under low water conditions.);

- Fescues (*Festuca* spp.) - best for suited for roughs, but may be blended for fairway use where shade and low water resources are available. Will not stand heavy wear.

- Perennial Ryegrass (*Lolium perenne*) - many varieties; best suited for tees and fairways.

To select the appropriate turfgrass type or mix, it is important to evaluate the specific situation, how the turf will be used, and the characteristics of the various turfgrass types. For best results, it is recommended that only *named* varieties of turfgrass be used.

Grasses suitable for the Pacific Northwest that will withstand wear similar to that imposed on golf fairways and that have lower water demand do not currently exist. Development and research into such varieties continues. The creeping bentgrasses may be used for this purpose primarily because they will recover from summer stress. Their ability to recover is a result of their well-developed stoloniferous (above-ground lateral stems) growth system. Since creeping bentgrasses are more subject to disease infestations than some other turfgrasses, they may require greater use of fungicides.

Table 5-3. Potential Water Savings from Conservation Measures

Area of Savings	Water-Conserving Course	Conventional Course	% Water Savings
Semi-arid Grasses	bentgrass, fescue	bluegrass, fescue	15
Irrigated Turfgrass Area	137 acres	180 acres	20
Irrigation System	computerized*	non-centralized; lacking probe inputs	30 - 40
Water Reuse	dependent upon supply		
Low Water Species Use	considered as reduction in irrigated course size		5 - 10
Potential Cumulative Savings (exclusive of water reuse)			47 - 57

*Automated and centrally controlled using evapotranspiration data.

Fine fescues will survive significantly lower levels of water than most other turfgrasses. However, they are bunch grasses and will not withstand wear. Consequently, these grasses are not suitable as the main species in fairway seedings. After they become established, they are often persistent in golf course roughs.

Preemergence or postemergence control of annual bluegrass on putting greens and fairways is not easily accomplished. Good cultural practices that promote growth of the desired species and reduction of injury from disease and compaction, and thereby increase the competition to annual bluegrass, should be the basis for integrated pest management involving annual bluegrass. Proper irrigation management, control of minimum cutting heights, appropriate aerification and balanced fertilization that includes sulfur are fundamental ingredients. In newer turfs, the use of preemergence and postemergence herbicides may provide an additional tool for the maintenance of more favorable turf species that will withstand the pressures of lower water availability. The control of annual bluegrass through biological control with the bacterium *Xanthomonas campestris* may be useful in the future. With proper precautions (see section 9.1), endothall can be used for postemergent control of annual bluegrass (Washington State University Cooperative Extension, Bulletin EB 1129; Annual Bluegrass Control in Turfgrass for Commercial Applicators). Most area courses do not attempt to control annual bluegrass or any grassy weeds with herbicide treatment.

Proper irrigation managment is critical to promote healthy turfgrass, which will in turn result in lower water, fertilizer and pesticide requirements.

Limiting Size of Irrigated Turf Area (approximately 20% reduction in irrigation demand)

Golf courses in water-conscious regions are often smaller in irrigated-area size, which reduces water consumption. Generally, eighteen hole golf courses in semi-arid regions average less than 140 total acres in size, compared with conventional courses of 180 to 210 total acres in size. Irrigated areas on conventional courses are usually about 80 acres. Design features include clearly defined boundaries between the turfgrass and surrounding landscape and land uses. Shrinking the size of the irrigated portion of the course is usually accomplished by narrowing fairways, more strictly defining landing areas for each shot and narrowing the rough, which increases the difficulty of play. Taken to extremes, the increased difficulty can be incompatible with public course play objectives.

Use of Low Water Use Vegetation (savings dependent on acreage of water-requiring plantings eliminated)

The design and layout of a golf course should incorporate or maintain the adapted vegetation adjacent to the golf course areas of play, and utilize low water use or adapted species in landscape plantings (reference Section 4.1).

Computer Controlled Irrigation (up to 30 to 40% reduction in irrigation demand)

Modern golf courses should incorporate a technologically modern, centrally controlled irrigation system (reference Section 5.3; Irrigation Systems). The use of a computer to control irrigation conserves water as well as management time and money. The most efficient systems use feedback from soil moisture probes or probes monitoring wind, precipitation, humidity, and/or air temperature to calculate evapotranspiration, and supply only the amount of water actually needed. This allows the irrigation system to adjust to natural weather conditions.. The Redmond City Parks Department reports a 30 percent to 40 percent savings in water use since installation of a system that was developed for golf course management in City parks (D. Tuchek, City of Redmond, pers. comm. 9/18/92). The benefits of such a system are numerous and include the following:

- Ability to irrigate the course in smaller, more discrete units (a function of fine scale irrigation system design during course construction).

- Control of distribution and timing, and control of irrigated depth to the root zone to supply only the water needed. For example, 30 minutes of irrigation can be applied over several hours, allowing for a correct watering depth on sloped areas, but preventing surface runoff.

- Labor Savings and Flexibility. The central irrigation system should be continually adjusted and managed by the course superintendent to reflect irrigation needs over changing seasons and conditions (reference Section 5.3, Irrigation Systems.)

- Water savings. Generally speaking, with a knowledgeable operator and good design, a centrally controlled irrigation system will perform at 80 percent or better efficiency.

Treated Wastewater Reuse

Use of reclaimed wastewater for irrigation should be investigated wherever possible. The potential for water reuse throughout King County will clearly be a function of proximity to a reclaimed water source. In areas with potential but no immediate water reuse sources, dual plumbing systems could be installed to allow eventual transition to reclaimed wastewater. The Washington State Department of Health, in association with the Washington State Department of Ecology, has issued draft water-reuse standards for public comment. Article 4, Section 2, of the Draft State of Washington Water Reclamation and Reuse Criteria (Irrigation of Nonfood crops) specifies that reclaimed water for golf courses *"...shall be at all times an oxidized, filtered, disinfected wastewater. The wastewater shall be considered adequately disinfected if the median number of total coliform organisms in the wastewater after disinfection does not exceed 2.2 per 100 milliliters, as determined from the bacteriological results of the last 7 days for which analyses have been completed, and the number of coliform organisms does not exceed 23 per 100 milliliters in any sample."* Washington State interim standards applicable to golf courses are anticipated in early 1993. The U.S. Environmental Protection Agency is also preparing national water-reuse standards. The EPA may utilize fecal coliform rather than total coliforms to determine reuse standards.

Comparison of potable versus treated effluent water for golf course irrigation on turf grass has been made in the Southwest, where irrigation with sewage effluent is a common practice. Although grass species and climatic differences are large between arid regions, where sewage effluent is an irrigation source, and King County, where such irrigation is in its infancy, the practice appears consistent with turf management objectives of golf courses in the northwest, with some alteration to cultural practices. Secondary effluent was reported to reduce germination of some grass species, probably because of a greater salinity or ammonium content. However, seeding establishment was superior to potable water after one month, which was attributed to the effluent being a fertilization source (Hayes et al. 1990). After four months, turf plots irrigated with potable water and fertilized were superior to plots irrigated with secondary effluent. Treatment of the effluent plots with foliar iron was necessary to prevent chlorosis after fertilization. Sodium, soluble salts and total phosphorous tended to accumulate in the effluent plots. These differences can be dealt with by changing management practices, such as increasing the seeding or watering initially with potable water to increase seed germination; eliminating or reducing phosphorous fertilization; reducing nitrogen fertilization; treatment with foliar iron to prevent chlorosis; and increasing applications of soil or water amendments such as gypsum to maintain adequate leaching and prevent build-up of salts (Hayes et al. 1990).

Valuable water reuse references are: J. Crook, 1990. *Water Reclamation*. Academic Press, Inc.; and R.W. Crites. 19??. *Wastewater Reuse by Golf Course Irrigation in California*. In addition, Metro is completing a Baseline Risk Assessment for wastewater reuse, expected to be completed by December 1992. Contact Denise Taylor of Metro at 624-1217 for more information.

On-site Reservoir Storage (lowers peak water rate consumption)

Aesthetic or water features designed for course play objectives can provide several functions in the management of a golf course:

- stormwater quality/quantity control; and,
- providing a secondary source of irrigation water to lower peak water demand rates by reservoir drawdown, or to allow for interruptable supply of irrigation water.

Depending upon the size and maximum potential change in water surface elevation (usually restrictive for both aesthetic and play water bodies), considerable reduction in peak water rate requirements can be achieved. The water balance computation should indicate the savings in peak consumption.

Water Management Plan

A water management plan should be developed when the golf course is designed. This plan should address contingency planning as well as normal ongoing operations. The contingency plan should address the local supplier's plans with respect to water shortages and should outline a strategy to deal with possible interruptions to water supply for shortages or other reasons. Strategies could identify limitations that could be applied to irrigated areas during a shortage, or for reservoir water levels to be lowered beyond normal limits (assuming reservoirs are sufficiently sized). The water balance should indicate the projected minimum, as well as the average, water requirement for utility planning purposes.

The ongoing operations portion of the plan should outline pertinent information related to design parameters of the landscape and irrigation systems, and should also identify the training needed for staff to deal effectively with water management issues.

5.3 Irrigation Systems

This section is a brief overview of some irrigation techniques, and is not intended to be a complete description of irrigation systems.

Selection of proper turfgrass types, proper design of the irrigation system, use of appropriate management strategies, and adoption of an appropriate management attitude are all factors in minimizing irrigation water use. The irrigation system can be designed to include weather monitoring stations, canopy temperature indices, electronic sensing devices, open evaporation pans, tensiometers or soil moisture sensors. These instruments, coupled with visual observation of turf conditions and irrigation feedback software systems that report actual use and report deviations in supply, can help to specifically determine accurate irrigation water use rates and need, and thus prevent a waste of water resources. Regardless of the irrigation technology used, water need will vary with weather and other factors and the irrigation schedule should conform as closely as possible to actual water need.

Computers are now able to assist the turf manager with making irrigation related decisions. Computer generated data bases coupled to electronic weather stations help to provide accurate, reliable irrigation scheduling information. When computer generated scheduling programs are coupled to single-wired irrigation hardware, the turf manager has considerable irrigation system flexibility and control. This in turn helps to prevent waste of water, and helps to prevent nutrient or pesticide related leaching or run-off. For efficient operation, the computer requires precise programming.

Generally, there is an eight to ten hour window available for irrigating the entire course on any given day. This window often requires flow volumes through the system of 1,000-2,000 gallons per minute, depending on the size of the course. Using a computerized irrigation system can enhance irrigation efficiency through flow management. Flow management allows various portions of the irrigation system to operate simultaneously, thereby maintaining an optimum system flow rate. Flow management conserves water, conserves time, conserves electrical power to the pumping station, and also helps to promote a healthy, vigorous turf by maintaining an adequate flow of water to areas requiring irrigation.

The design of an irrigation system is a complicated process, and should only be undertaken by a qualified designer based on information from local turfgrass experts. Irrigation specialists and course designers should ensure that sprinkler design, spacing and control are correct for each hydrozone, or cluster of areas with similar watering needs (whether that be turfgrass or other course plantings). Contractor performance when installing the system is equally important. The irrigation system should be audited by a certified irrigation auditor prior to acceptance to ensure it was installed as designed. Annual audits by golf course staff are recommended to determine actual efficiency and the need for system adjustment.

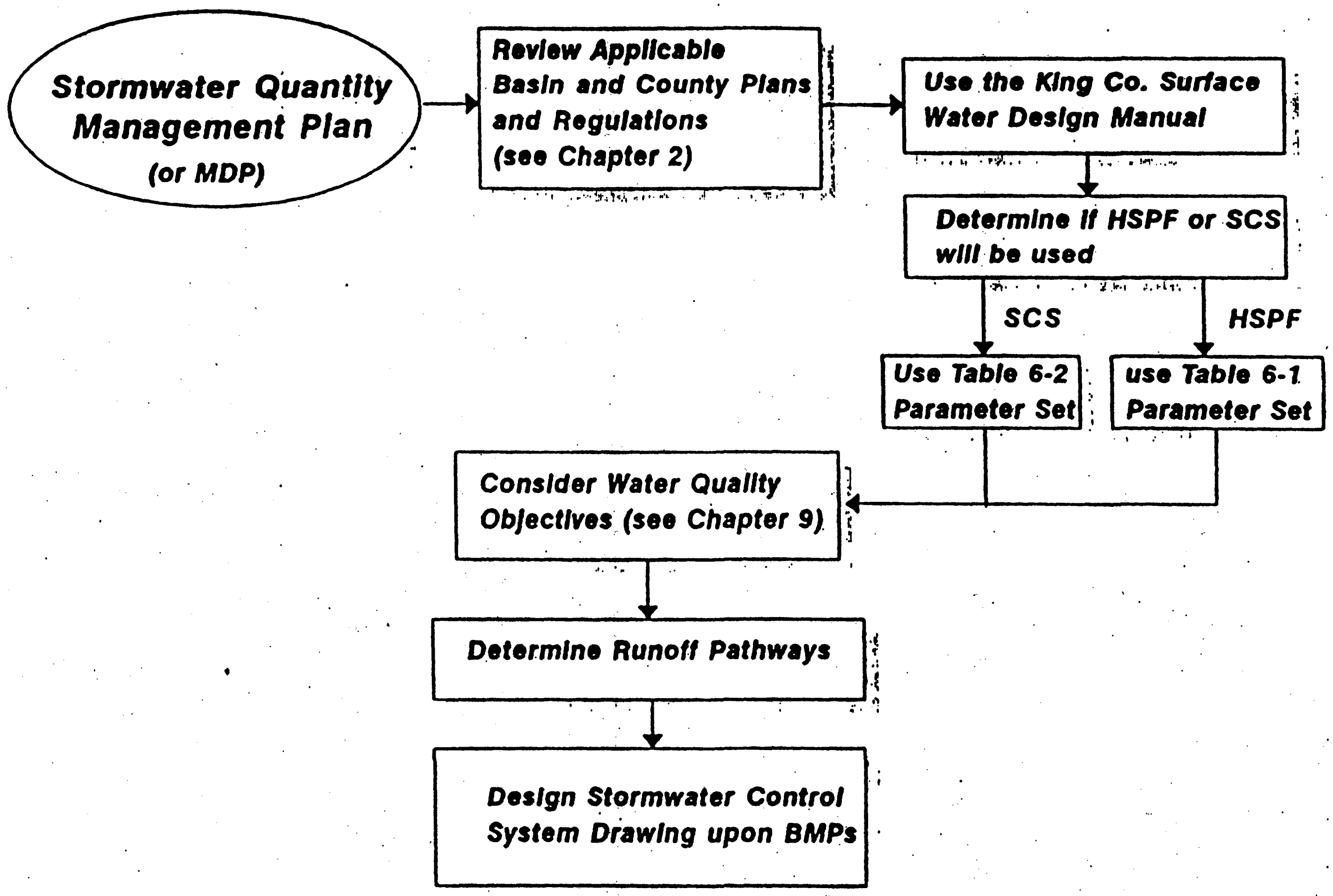
Sprinkler Head Control

Sprinkler heads can be wired to irrigate single sprinklers from a given computer station. This is especially useful on stations that may require frequent waterings of short durations (such as slopes, dense subgrades, etc.). The VIH sprinkler head is pressure regulated, which ensures that the same amount of water will be discharged from each sprinkler regardless of distance from the supply or the elevation of the head (assuming that there is sufficient pressure to provide the proper flows at the highest and/or furthest point on the course).

Heads without pressure regulation are most frequently labeled as a "battery system" or "block system" wherein two to six (or more) heads are on the same automatic valve (control station). "Battery" or "block" systems do not relate as well to soil density, slope, shade, etc. as the VIH systems, and consequently do not benefit as much from automation. In addition, the VIH pressure regulated head can be manually eliminated from any station, and can be manually operated to provide supplemental water without affecting companion heads on the same control station.

A relatively new practice using sprinkler heads is to require that the "hot wire" from the satellite to a station with multiple heads be wired all the way back to the base of the satellite. This affords the operator the ability to alter the original irrigation schedule by switching wires at the satellite to suit "discovered" wet spots, dry spots, or of combining sprinklers that are better suited to the course than the original design may have provided. The ultimate design, one with the maximum control possible, would have one sprinkler head on each station of a satellite. This would require a significant number of satellites, but would offer the most stringent water control.

CHAPTER 6 - Hydrology and Stormwater Quantity Control



Hydrology And Water Quantity Control

Summary of Best Management Practices

When designing a stormwater control system for a golf course, the objectives of employing Best Management Practices should be:

- reducing peak rates and volumes of runoff;
- minimizing surface runoff; and
- minimizing the potential for pesticide and fertilizer washoff.

The following general practices should be adopted in order to achieve the above-stated objectives:

- For originally forested areas, the minimum possible area should be cleared for course construction.

- Areas devoted to tees, greens and fairways should be minimized to the extent compatible with the intended users (standard of play) of the course.

- Mature trees and deep rooted shrubs should be maintained or planted in the rough to the extent possible.

- The rough should be planted in relatively deep rooted, drought resistant grass species and maintained to the maximum length consistent with the intended standard of play. Maximum use of non-irrigated rough is strongly recommended.

- Minimum buffer and setback requirements for streams, swales, and wetlands should be as mandated in the King County Sensitive Areas Ordinance.

- Constructed drainage swales should be built within the rough and kept out of the fairways to the extent possible.

- On till or bedrock soils, minimum soil depth to till or weathered bedrock should be one foot. Where grading or clearing has reduced soil depths to less than one foot, a sandy loam or equivalent permeable soil should be imported.

- Application of agrichemicals should be avoided during winter months (November through March) in areas susceptible to periodic flooding.

6.0 Hydrology And Water Quantity Control

6.1 Introduction

Conversion of forest lands or farmlands to golf courses may result in increased stormwater runoff which, in the absence of appropriate mitigation measures, could lead to increases in downstream flooding and stream channel erosion. In addition, if not managed properly, fertilizers, herbicides and other agricultural chemicals used in golf course management may adversely impact both groundwater quality and water quality in downstream water courses and water bodies. The design of appropriate measures to mitigate for these potential impacts requires a detailed analysis of the site's hydrology and an understanding of the dominant hydrologic processes.

This section provides an overview of the regulatory requirements governing design of a stormwater control facility, discusses techniques for determining runoff and designing an effective control system, and outlines best management practices that can be implemented to reduce the potential for stormwater runoff impacts.

6.1 Regulatory Requirements

A variety of ordinances that specify measures required to control increased runoff associated with development are currently in place in King County. These include the 1990 Surface Water Design Manual (updated in 1992), P-suffix conditions in Community Plans, administrative rules in critical drainage basin designations and policies in individual basin plans for specific areas in King County. While these ordinances are generally oriented toward residential or commercial development use, they are equally applicable to golf course development.

Requirements for stormwater control in King County have evolved over the years. Under existing ordinances, stormwater control facilities are generally required to control the post-development 2- and 10-year peak runoff from a site to the pre-development peak rates. However, a number of more stringent requirements have been imposed in areas requiring additional protection from flooding and stream channel erosion. Stormwater control is typically achieved through the construction of infiltration and detention ponds. For the majority of projects, the County currently requires that stormwater control facilities be designed using runoff data as predicted by the Santa Barbara Urban Hydrograph (SBUH) version of the Soil Conservation Service (SCS) method with a 24-hour design storm. For projects where a Master Drainage Plan (MDP) is required (as specified in the 1990 Surface Water Design Manual), the County has typically required runoff data to be estimated using the U.S. Environmental Protection Agency's more sophisticated HSPF model.

Use of the SBUH Method with a 24-hour design storm to predict stormwater runoff was mandated in the 1990 Surface Water Design Manual. Since adoption of the Manual, it has been found that detention facilities designed using the SBUH method may not meet their stated performance goals. Work is currently in progress to develop a new technique for estimating stormwater runoff that would provide design of control facilities with improved performance capabilities. Two possible approaches are currently being explored; modification of the existing SBUH method, and development of a simplified version of the HSPF method using what is referred to as a "runoff file" approach. While a decision has not been made as to which method will ultimately be adopted, both methods are intended to produce designs which better meet stated performance goals. Whichever technique is adopted should be used for designing stormwater control facilities for golf courses. It should be noted, however, that with either method (as well as with other existing methods), the accuracy of runoff estimates for golf courses (and hence the reliability of designs) is affected by the lack of basic data available to determine model parameters, as discussed in more detail below.

6.2 Design of Quantity Controls

The principal feature of concern for hydrologic assessment of a golf course is the conversion of large areas of (typically) forest or farmland to intensively managed grassland. Consequently, the uncertain hydrologic response of grasslands warrants a greater level of attention than currently provided in the 1990 Design Manual.

Factors Affecting Runoff

In simplistic terms, sizing of detention facilities depends principally on pre-development peak flows (which form the basis for determining the required performance of control measures), and the volume of runoff in post-development hydrographs (which dictates the volume of storage required). The principal factors affecting runoff from a site are:

- meteorological and climatic conditions,
- soils and surficial geology, and
- land use or cover type.

Meteorological Conditions

Meteorological conditions are reasonably well established throughout western King County. Rainfall data published in the 1990 King County Surface Water Design Manual and weather data published by the National Oceanic and Atmospheric Administration should be adequate for any analysis west of a line running approximately north to south from between Duvall, North Bend and Enumclaw. Conditions in the more mountainous eastern portion of the County are highly variable, and special studies or analyses of precipitation data may be required for developments in this area. Particular consideration may need to be given to snow accumulation and melt for sites more than about 1,500 feet above sea level. Above that elevation, rainfall runoff in major events may be augmented by snowmelt.

Soils and Surficial Geology

A good general indication of the soil types and surficial geology on a site can be determined from soils mapping of King County performed by the SCS, or maps of surficial geology published primarily by the U.S. Geological Survey or the Washington State Department of Natural Resources. However, detailed site-specific mapping of soils and surficial geology should be done by a qualified geologist or geotechnical engineer prior to site selection or golf course design.

For convenience, four general soil/surficial geology classifications can be considered:

- deep, highly permeable outwash soils (outwash soils - SCS Hydrologic Soil Groups A and B);
- shallow surface soils overlying relatively impermeable glacial till (till soils - SCS Hydrologic Soil Group C);
- shallow surface soils overlying bedrock (bedrock soils - SCS Hydrologic Soil Groups B and C);
- fine textured alluvial soils in flat valley bottoms with a seasonally high water table (alluvial soils - SCS Hydrologic Soil Groups C and D).

The majority of soils subject to development in western King County are till soils. For the purposes of this discussion, bedrock soils and till soils will be treated as having the same hydrologic response and will be referred to collectively as till soils.

Mapping of outwash soils should be examined with care. In some situations, soils mapped as outwash are actually underlain at relatively shallow depth (perhaps as little as 5 foot) by relatively impermeable glacial till. In this situation, saturation of the soil horizon can occur, especially in areas that are very flat or in which subsurface flows converge. Areas of outwash soil subject to saturation because of underlying tills should be treated as till soils.

Land Use and Cover Types

The final principal factor affecting runoff from a site is land use, and perhaps more importantly from the point of view of designing storm water control measures, the change in land use resulting from the golf course development. Because of the large areas and associated cost of land required for golf courses, this discussion will assume conversion of forest lands or farmland to golf courses.

Prediction of Runoff Rates

As previously discussed, the techniques to be used for estimating pre- and post-development runoff rates for developments in King County are mandated through storm water control ordinances. Under current regulations, runoff rates are predicted using the SBUH method with a 24-hour design storm or via HSPF for large projects. However, as also pointed out above, the current implementation of the SBUH method appears to underestimate detention pond sizes required to meet specific levels of control, and modifications to the SBUH method are being investigated.

With planned modifications, it is the County's intent that both HSPF and the modified SBUH method will be able to provide designs that meet stated performance standards. Consequently, the following discussion will concentrate on the selection of model parameter values (which govern the hydrologic response predicted by the model) and incorporation of uncertainty in design. In either case, availability of observed flow data and comparison of these data with model predictions are of fundamental importance.

HSPF Model Parameters

The hydrologic response of forest lands in King County has been documented relatively well over the last few years through monitoring efforts conducted by the U.S. Geological Survey, King County and private developers (those required to prepare Master Drainage Plans). Good quality streamflow data are available from several sites. These data have been used to develop relatively reliable parameter estimates for HSPF which in turn provides the basis for making modifications to the SBUH method.

Unfortunately, there are very few good quantitative data on the hydrologic response of various types of grassland in western Washington. Research conducted during preparation of this manual did not uncover any local runoff data from golf courses. Reliable estimates of the hydrologic response of grasslands can be important both for assessing pre-development runoff rates (for example in the event of conversion of pasture land to golf course) and for determining post-development runoff rates and volumes. A limited amount of data have been collected by the U.S. Geological Survey and King County from residential areas where runoff from lawns provides a significant contribution to overall runoff volumes. However, model parameters for this "urban" grassland would probably overestimate runoff from a well managed and maintained golf course. HSPF parameter sets for "urban" grassland should provide an upper bound on the post-

development runoff rates and volumes from a golf course.

Recommended HSPF parameters by cover and soil type pertinent to golf course development are provided in Table 6-1. The "pasture" parameter set should be used when the pre-development condition is farmland. The "golf course" parameter set should provide a somewhat conservative estimate of post-development runoff. This parameter set provides for lower post-development runoff volumes than the "urban grass" parameters. Pond volumes computed using these parameters should be increased by a safety factor of 20% (or other factor as directed by King County) to account for construction/maintenance deficiencies and other uncertainties.

Model parameters provided in Table 6-1 only include till and outwash soils. No generalized HSPF parameter estimates are available for fine textured alluvial soils at present.

SCS Model Parameters

The existing model parameters for the SBUH model contained in the King County Surface Water Design Manual generally do not appear appropriate for designing detention facilities for golf courses. It is not clear, at the time of writing, whether potential modifications to the SBUH method will produce a model in which currently published parameters are still appropriate. One of the principal difficulties in using the SBUH method is that it significantly overestimates pre-development peak flow rates from pasture land. Because pre-development flow rates determine target post-development flow rates, overestimation of pre-development peak flows result in target releases from detention facilities that are too high. The overall result is that pond storage volumes are too small.

In conversion from forest to golf course, overestimation of pre-development peak flows may be compensated to a large extent by the model's overestimation of runoff from grassland under the current parameter set. However, there is unlikely to be similar compensation in conversion from pasture or farmland to golf course. In the absence of more definitive information, the parameter set given in Table 6-2 should be used. Pond volumes computed using these parameters should be increased by a safety factor of 30% (or other factor as directed by King County). Both parameter estimates and safety factors should be modified as appropriate as more information becomes available.

6.3 Runoff Pathways

The pathways taken by stormwater runoff are important in determining the fate of water-borne fertilizers, pesticides and other agricultural chemicals. Of particular concern is the amount of runoff that occurs as surface runoff versus subsurface runoff (see Chapter 9). Rainfall rates in the Pacific Northwest are generally low

Table 6-1

HSPF Model Parameters

Parameter (1)

Land (2) Segment	LZSN (in)	INFILT (in/hr)	LSUR (ft)	SLSUR	KVARY	AGWRC (1/in)	INFEXP (3)	INFILD	DEEPFR	AGWET	CEPSC (in)	UZSN (in)	NSUR	INTFW	IRC (3)	LZETP
TF	4.5	0.0800	400.0	0.1	0.5	0.996	2.0	2.0	0.0	0.0	0.2	0.50	0.35	6.00	0.5	0.70
TP	4.5	0.0600	400.0	0.1	0.5	0.996	2.0	2.0	0.0	0.0	0.1	0.28	0.25	6.00	0.5	0.25
TGLF	4.5	0.0400	400.0	0.1	0.5	0.996	2.0	2.0	0.0	0.0	0.1	0.25	0.25	6.00	0.5	0.25
OF	5.0	2.0000	400.0	0.1	0.3	0.996	2.0	2.0	0.0	0.0	0.2	0.50	0.35	0.00	0.7	0.70
OP	5.0	1.4000	400.0	0.1	0.3	0.996	2.0	2.0	0.0	0.0	0.1	0.50	0.25	0.00	0.7	0.25
OGLF	5.0	1.0000	400.0	0.1	0.3	0.996	2.0	2.0	0.0	0.0	0.1	0.50	0.25	0.00	0.7	0.25

(1): Units are printed below parameter name, where units are not listed, parameter has no units

(2): Land segment definitions:
TF: till soils, forest, all slopes
TP: till soils, pasture, all slopes
TGLF: till soils, golf course, all slopes
OF: outwash soils, forest cover, all slopes
OP: outwash soils, pasture, all slopes
OGLF: outwash soils, golf course, all slopes

(3): Recession constants associated to daily flows compared with most other parts of the United States, and surficial infiltration rates for drained soils under natural conditions generally far exceeds rainfall intensities. However, subsurface conditions are often such that the potential may exist for grassland to generate significant quantities of surface runoff because of saturation of the soil horizon.

Table 6-2. SCS Model Parameters

	Curve Numbers by Hydrologic Soil Group			
Land Use	A	B	C	D
Forest	42	64	76	81
Farmlands (All Types)	55	72	81	86
Golf Course	68	80	86	90

As noted in Section 6.2, the following general soil groups will be considered:

- highly permeable outwash soils which contain a high percentage of sands and gravels.
- till or bedrock soils which are underlain at shallow depth by relatively impermeable glacial till or bedrock.
- alluvial soils on the flood plains of river valleys which may have a high water table during the winter months.

For deep outwash soils (SCS Hydrologic Soil Groups A and B) there will generally be no surface or near surface runoff from golf courses except in heavily trafficked areas where soil compaction results in locally reduced infiltration rates. However, as noted earlier, careful mapping of outwash soils is needed to identify underlying impermeable material that may result in saturation of the soil horizon during the winter months.

Till and bedrock soils are underlain at shallow depth by a relatively impermeable layer that severely restricts the downward movement of water. Stormwater movement then occurs either as lateral sub-surface movement above the impermeable material or as surface runoff when the soil horizon becomes saturated. Under forested conditions, available information indicates that little surface runoff occurs even under extreme conditions. However, storm runoff response is quite rapid and it is believed that relatively rapid **near surface** runoff through root holes, burrows of small invertebrates and so forth (macropore flow) is the dominant runoff producing mechanism in major storm events (Beven, 1992).

A possible alternative mechanism for storm runoff generation is displacement of "pre-event" water (see Chapter 7), in which lateral sub-surface flow velocities are an order of magnitude lower than the macropore flow.

In conversion of forest land to grass lands, the native surface soils are extensively disturbed by clearing and grading and most macropores are eliminated. Grading may also result in a considerable reduction in the soil depths above the impermeable layer. After conversion, subsurface and near surface flow will continue to occur from the golf course grasslands. However, during severe events surface runoff will be more prevalent than under forested conditions. Surface runoff will generally occur locally toward the bottom of hill slopes, on concave hill slopes and in swales (where subsurface flows are concentrated and the soil horizon becomes saturated), and in areas with heavily compacted soils or with minimal soil cover above the till or bedrock layer. The proportion and spatial distribution of surface runoff will depend on detailed topographic features and soil depths, a discussion of which is beyond the current scope of this publication.

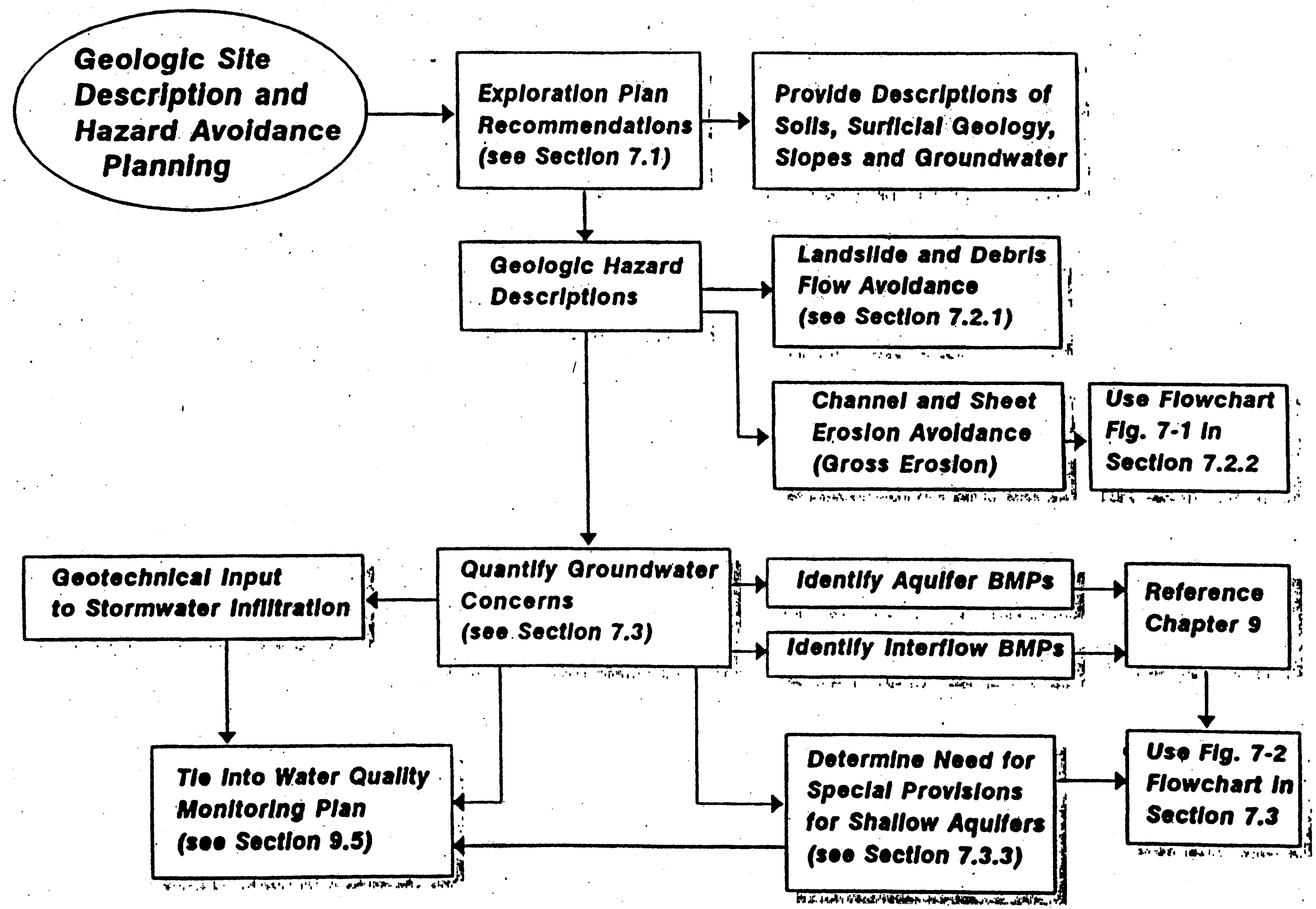
An approximate and generalized estimate of the proportion of surface or near surface runoff from grassed areas was determined by computer modeling with HSPF. According to the model results, approximately 10% of total runoff occurs as rapid response surface or near surface runoff. This percentage is more or less independent of season, although summer runoff is, of course, only a small fraction of total annual runoff. As pointed out previously, there are only very limited data on the hydrologic response of grassed areas and this figure should only be used as a general guide. The data on surface and near-surface flows represent both surface runoff and rapid near-surface runoff through the root structure or thatch of the turf. Flows of this type will have travel times on the order of minutes as against travel times on the order of hours for subsurface flows.

Alluvial soils on the floodplains of the major river valleys in King County present a final major category of soils subject to conversion from farmland to golf courses. These soils are generally poorly drained with a high fines content and a seasonally high water table. These soils may also be subject to periodic flooding. Although the surface soils may be relatively permeable in a drained condition, the presence of a high water table and the susceptibility to flooding provides a much greater potential for direct introduction or washoff of agricultural chemicals directly into either the groundwater system or into surface waters.

6.4 Future Research Needs

Section 6.2 of this manual introduces two possible approaches to developing new techniques for designing water quantity control facilities with improved performance capabilities. Development of either alternative approach for golf courses is hampered by a lack of basic data from which to determine model parameters. As a result, a conservative approach is recommended for hydrologic control of runoff from golf courses. Data on the actual impact of forest land or farmland conversion to golf course turf on water runoff need to be collected to verify the accuracy of the approaches and model parameters recommended.

CHAPTER 7 - Geology and Groundwater



Geology and Groundwater

Summary of Best Management Practices

- Establish a temporary erosion and sedimentation control plan (TESCP) developed by a licensed civil engineer.

- Stage clearing and grading to minimize the amount of cleared areas so that denuded soils can be revegetated within a maximum of 14 days following initial exposure. Denuded soils should be surface roughened to reduce water velocity in moderate erosion hazard areas.

- Avoid all unnecessary clearing, and avoid disturbing slopes greater than 40 percent and over 20 feet in height.

- Maintain natural buffers around wetlands, lakes, ponds and streams.

- Protect soil stockpiles against erosion and establish silt fencing below all construction zones.

- For moderate to high erosion hazard areas, the following measures should be employed:
  a. Clearing and grading should be timed to occur during the dry season (May through October).
  b. All surface flow should be directed to a stabilized drainage way.
  c. Sediment traps should be established.
  d. Graded terraces should occur every 20 feet in vertical height or 50 feet in slope length, whichever is less.
  e. Erosion controls should be inspected by a qualified inspector weekly or immediately after more than 1.0 inches of rain in 24 hours.

- For high erosion hazard areas, existing should be preserved to the maximum extent possible.

- Soils supporting the interflow network should be protected from compaction by machinery. Areas with compacted interflow network soils should be loosened prior to turf placement. Areas excessively compacted that cannot be loosened should have a minimum of 12 inches of sandy loam or original topsoil placed atop the compacted zone. Areas with interflow network soils mostly or completely removed should have a minimum of 18 inches of sandy loam or the original topsoil placed under the turf.

- Depth to groundwater should be established at each green and tee during the wet season. If depth to groundwater is less than 25 feet, monitoring wells should be established on the course. If the depth to groundwater is less than 4 feet and the soils are coarse-textured, special provisions should be taken (see Section 7.3). If interflow is proposed for stormwater treatment, the provisions in Section 7.4 should be followed.

7.0 Geology and Groundwater

Geologic concerns related to golf course development include steep slopes, landslide hazards and erosions hazards. In addition, geologic conditions, such as slope, soil types and underlying parent material determine the potential for golf course development and management to affect the flow of nearby streams, recharge to wetlands or quality of underlying groundwater resources. This section discusses techniques for evaluating these geologic conditions and provides Best Management Practices for golf course design and operation to mitigate possible adverse effects.

Note: Construction-phase Temporary Erosion and Sedimentation Control Planning (TESCP) is not addressed in this Manual edition.

7.1 Geologic Mapping Requirements

Design of a golf course must consider, among other things, the natural geologic conditions of a site. In order to properly evaluate the geologic conditions, sufficiently detailed soils, surficial geology, and slope maps should be provided.

The soils and surficial geology maps should be based on site specific subsurface explorations that are evaluated by a qualified geologist. The explorations may be either backhoe pits or drill borings, but should be a minimum of 10 feet in depth, except when bedrock is encountered. The explorations should be of sufficient number to adequately define the surficial soils and geology. A suggested exploration plan would include one subsurface exploration on each proposed tee and green location. In addition, a single subsurface exploration near the midpoint of a par 3 fairway and two, approximately equal spaced explorations, on each par 4 and par 5 fairway, may be necessary.

If the subsurface explorations indicate that any tees or greens are underlain by coarse textured soils (SCS Hydrologic Soil Groups A and B), it will be necessary to establish site specific depth to groundwater, or to establish that groundwater is not within 25 feet of ground surface in these areas during the wet season. This may require subsurface explorations a maximum of 25 feet in depth and the establishment of monitoring wells to test for course management pesticides. Nitrate from fertilizers can penetrate to any depth and must be addressed as a separate concern. Available water well logs should be acquired and reviewed to aid in the determination of depth to groundwater. These maps may indicate that local groundwater is too deep to be of concern, which would negate the need for deeper explorations and monitoring wells (see Section 7.3, Construction in Shallow, Upper Aquifer Areas discussion).

A slope map should be prepared with the following delineations clearly outlined and labeled.

a. 0 - 7 percent slope
b. 8 - 15 percent slope
c. 16 - 40 percent slope
d. Greater than 40 percent slope

7.2 Geologic Hazards

Geologic hazards that should be identified during preliminary golf course design include landslide and erosion hazard areas. Best Management Practices to mitigate the risk associated with these areas during construction are discussed below.

Landslides

Landslides (and/or debris flows) are a common occurrence in King County. Most often these events are related to steep slopes, poor soils and adverse water conditions. The adverse water conditions are often linked to groundwater, but may also be surface water related. Fill over steep slopes and seismic impacts may also affect slope stability.

Avoiding all disturbance of slopes greater than 40 percent and over 20 feet in height will reduce the risk of landslides from golf course development. Slope disturbance includes, but is not limited to, vegetation removal, grading and uncontrolled stormwater discharge. In addition, any fill to be placed on greater than 20 percent slopes must be properly keyed, benched and compacted.

The owner/developer must recognize that some slopes are inherently unstable and more severe mitigations may be required. Site specific recommendations by the geologic consultant would be required in these instances.

Erosion

Increased channel and sheet erosion have long been recognized as potential byproducts of golf course development, especially during construction phases. Modification of stream channels in response to changing land use practices within King County has previously resulted in significant impacts to properties downstream and adjacent to the streams, as well as to fish habitat throughout the stream's reach. Increased volumes of stream sediment transport and downstream sedimentation has occurred at numerous locations, as evidenced by fine sediments settling in bodies of standing or slow moving water, and coarse sediments plugging culverts and blocking the course of stream corridors. Oversteepening of slopes adjacent to streams has also occurred, which increases the landslide and debris flow hazard, thereby providing additional sediment for downstream transport.

Taken together, the cumulative effects of these impacts have the potential to adversely impact downstream environments.

In order to evaluate potential erosion impacts as a result of proposed golf course development (and subsequently provide mitigation), it is important to understand where and how the sediment arrives at the receiving waters. The sediment begins to move by a process called gross erosion (Figure 7-1) which can be broken down into sheet erosion and channel erosion.

Different soil types and geologic parent materials can have widely differing susceptibilities toward each separate erosive regime. As an example, Vashon till develops a soil horizon atop the unit that is commonly called the Alderwood Soil Series. The soil is significantly less dense than the geologic parent material; however, it contains about the same percentage of fines (smaller than 0.08 millimeters) as the parent material. The soil material is susceptible to both sheet and channel erosion due to its lower density and high percentage of fines. However, the geologic parent material is significantly less susceptible to either erosive regime for a given storm event, due to its high density and cohesive nature. Therefore, the sheet erosion potential can be estimated by employing the Universal Soil Loss Equation (U.S.L.E.) with generally acceptable results except on slopes with steep gradients.

Conversely, the Vashon advance, or subglacial, outwash unit, develops a soil horizon termed the Indianola Soil Series. This soil is much less susceptible than the Alderwood Soil Series to sheet erosion, primarily due to its high permeability, which prevents the development of sheet flow during normal rainfall events. However, both the soil and the parent material (mostly sand with scattered gravel) are highly susceptible to erosion under concentrated flow regimes (channel erosion). For this reason, the volume of sediment available, as determined by the U.S.L.E., may be overwhelmed by additional sediment available as a result of gully and stream channel erosion, even on moderate slopes. As such, prevention of concentrated flow regimes will be the best mitigation of erosion when these geologic conditions exist.

Erosion is also a function of slope gradient. Therefore, during design of the golf course, erosion hazards should be identified as follows.

- High erosion hazard - all slopes greater than 40 percent.
- Moderate to high erosion hazard - 16 to 40 percent slopes.
- Moderate erosion hazard - 8 to 15 percent slopes.

Types of Groundwater Regimes

There are two separate groundwater regimes common in King County that may be affected by golf course development and that provide the basis for Best Management Practice guidelines. These regimes are identified as interflow and aquifer systems. A detailed description of each follows.

Interflow

Interflow is defined as the zone of horizontal water movement within a soil that has a higher hydraulic conductivity than the geologic parent material, such as Alderwood soils atop lodgement till (SCS Hydrologic Soil Group C). Interflow is always found at shallow depths (1 - 5 feet), may be substantial in quantity and may, in some basins, contribute significantly to total stream flow and/or wetland recharge.

The overall mechanism of interflow is not well understood. Some research studying interflow atop till soil suggests that water moves at a fairly rapid rate (hydraulic conductivities on the order of 280 feet/day and average velocities of 130 to 140 feet/day on 10% slopes) aided by macropores found within the soil. Other research, utilizing oxygen isotopes, indicates that water entering streams and wetlands from the interflow regime is dominated by pre-event water which was already stored within the soil layer (Rodhe, 1988). This research suggests that the actual rate of water movement within the soils is much lower with hydraulic conductivities on the order of 28 feet/day and average velocities of 15 feet/day on 10% slopes. Recent laboratory modeling suggests that the higher reported conductivities (macropore study) represent a pressure pulse of pre-existing, stored water through the soil. This modeling also reported hydraulic conductivities in close agreement with the oxygen isotope study. Therefore, it appears that the oxygen isotope study (pre-event theory) represents actual *in-situ* conditions. See Appendix F for a more detailed discussion of pre-event theory.

Continued research on interflow is recommended. Best Management Practices for construction in areas which contain an interflow network are provided below.

Aquifers

The second common groundwater regime forms below the interflow zone, and is referred to as an aquifer. An aquifer is defined as a zone of water saturation within a geologic stratum in which the water can be withdrawn for human use.

When the geologic parent material has a hydraulic conductivity equal to or greater than the soils that form atop the parent material, such as Everett soils above highly permeable outwash sediments, surface water is able to rapidly infiltrate through an unsaturated zone to recharge the underlying aquifer system. When this occurs with no intervening impermeable stratum (aquitard), and the aquifer is within 25 feet of the proposed ground surface, migration of some soluble pesticides and fertilizers could reach the aquifer. This is discussed in the section, Construction in Shallow Aquifer Areas, below.

Construction in Interflow Areas

If golf course construction will occur in areas that have an interflow network (generally in areas underlain by SCS Hydrologic Soil Groups C and D, but can be Soil Group B if the parent material is bedrock), the following Best Management Practices guidelines should be implemented.

- The soils that support the interflow network should be protected from compaction by machinery. This would include avoiding, or minimizing, traffic in these areas. In lieu of rubber tired equipment, tracked equipment should be utilized to reduce bearing pressure on the soil during clearing and grading operations.

- Areas where the interflow network soils have been excessively compacted should be loosened prior to turf placement. This could be accomplished by ripping or excavating and replacing the soil using wide tracked equipment. Regardless of the methodology, the loosening effect must extend for the full depth of the compacted soil.

- Areas that have been excessively compacted and cannot be effectively loosened should have a minimum of twelve (12) inches of sandy loam, or original topsoil material, placed atop the compacted zone to increase interflow capability of the soils.

- In areas where the interflow network soils have been mostly, or completely removed, a minimum of eighteen (18) inches of sandy loam, or the original topsoil, must be placed below turf level.

Construction in Shallow Aquifer Areas

If golf course construction will occur in areas underlain by a shallow aquifer (generally in areas containing SCS Hydrologic Soils Groups A and B), the following Best Management Practices guidelines should be implemented.

- Depth to groundwater must be established at each green and tee. These data may be available based on local water well logs. If not available, depth to groundwater must be established based on site specific subsurface information.

- If depth to groundwater is less than 25 feet, monitoring wells shall be established immediately downgradient on selected tees and greens deemed most susceptible by the project hydrogeologist. If the tees or greens are to be constructed with an impermeable liner and drainage treatment controls, monitoring wells will not be required.

- A sampling plan should then be determined by the hydrogeologist and submitted to King County for approval. Once the sampling plan is approved, samples shall be obtained and submitted to a King County approved analytical laboratory for purposes of establishing the base line groundwater quality. All findings shall be reported to King County within one week of receipt.

- A long term groundwater monitoring plan/system should be established and submitted to King County for approval. Once approved, the monitoring plan will be binding on the owner/developer and all subsequent owners.

- The groundwater monitoring plan (see Section 9.5) and system should, at a minimum, provide the following components.

  1) A system tailored to fit site specific conditions and circumstances. The system should include, but not be limited to, the use of monitoring wells, lysimeters and vadose zone monitoring technologies. If monitoring wells are used, they should be completed according to Department of Ecology guidelines.

  2) A routine groundwater sampling/testing schedule of at least once every six (6) months. The sampling/testing schedule should be more frequent in the event that the test results indicate a need for more frequent sampling, i.e. elevated levels of contaminants are encountered.

- If any portion of a fairway, green or tee is located on coarse-textured soils (SCS Hydrologic Soil Groups A and B), and the groundwater table is 4 feet or less in depth, then one or more of the following steps should be implemented.

  1) Avoid the area with irrigated development;

  2) Convert the area to a low maintenance use (rough);

  3) Replant the area with a grass variety requiring minimal fertilizers, pesticides and irrigation;

  4) Fill the area with material that will increase the silt/clay and/or organic content in order to reduce soil permeability to less than 10^{-4} cm/sec and increase the depth to groundwater; or

  5) Fit the area with an underdrain system to collect leachate, which can then be treated through application to suitable soils or a sand-peat filter.

7.4 Stormwater Treatment by Infiltration

A number of effective practices have been developed for treating stormwater runoff from impervious surfaces. The three most effective techniques are the use of ponds (either extended detention or wet ponds), filtration and infiltration. Of these, infiltration is becoming the preferred stormwater management practice due to its ability to effectively treat runoff, control stream bank erosion, and recharge underlying aquifers. However, infiltration is not practical in all situations. The feasibility of using infiltration depends on the nature of the underlying hydrogeologic environment and should be determined by a qualified geologist. See Section 9.1 for a detailed discussion of stormwater quality treatment options.

Infiltration can only be allowed when the following conditions are met.

- The depth to the seasonally high water table, or an impermeable sediment layer or bedrock (aquitard), must be a minimum of 3 feet below the bottom of the infiltration device.

- The upper 3 feet of soil must have a permeability between 0.50 inches/hour and 2.4 inches/hour.

In addition to the above soil constraints, the following guidelines must be followed for sites utilizing infiltration.

- The infiltration device must be a minimum of 100 feet downgradient of septic systems and water supply wells.

- The infiltration device must be a minimum of 20 feet downgradient and 100 feet upgradient of building foundations.

- Infiltration devices may not be placed on slopes steeper than 15 percent and should be a minimum of 150 feet from the top of 40 percent slopes.

- Inflow to infiltration devices should pass through a grass lined swale to minimize the suspended solid load. Roof drains may flow directly into infiltration devices.

- A maintenance schedule should be developed and closely followed.

If a site is not suitable for conventional infiltration practices, then a wet pond/sand filter combination should be used. King County guidelines should be employed when designing a wet pond/sand filter for treatment of stormwater runoff.

7.5 Future Research Needs

Two current theories can be used to explain the mechanism for wetland and stream recharge from the interflow zone atop lodgment till. These may be named the 'macropore' and 'pre-event water' theories. Macropore theory suggests that water transport in the interflow zone is significantly enhanced by the occurrence of voids such as root tubes and animal burrows. As a result, high apparent hydraulic conductivities and high groundwater velocities are interpreted. Pre-event water theory suggest that the majority of stream and wetland recharge is from pre-event water or water that has been in storage prior to the current event. Hydraulic conductivities and velocities are generally at least an order of magnitude lower.

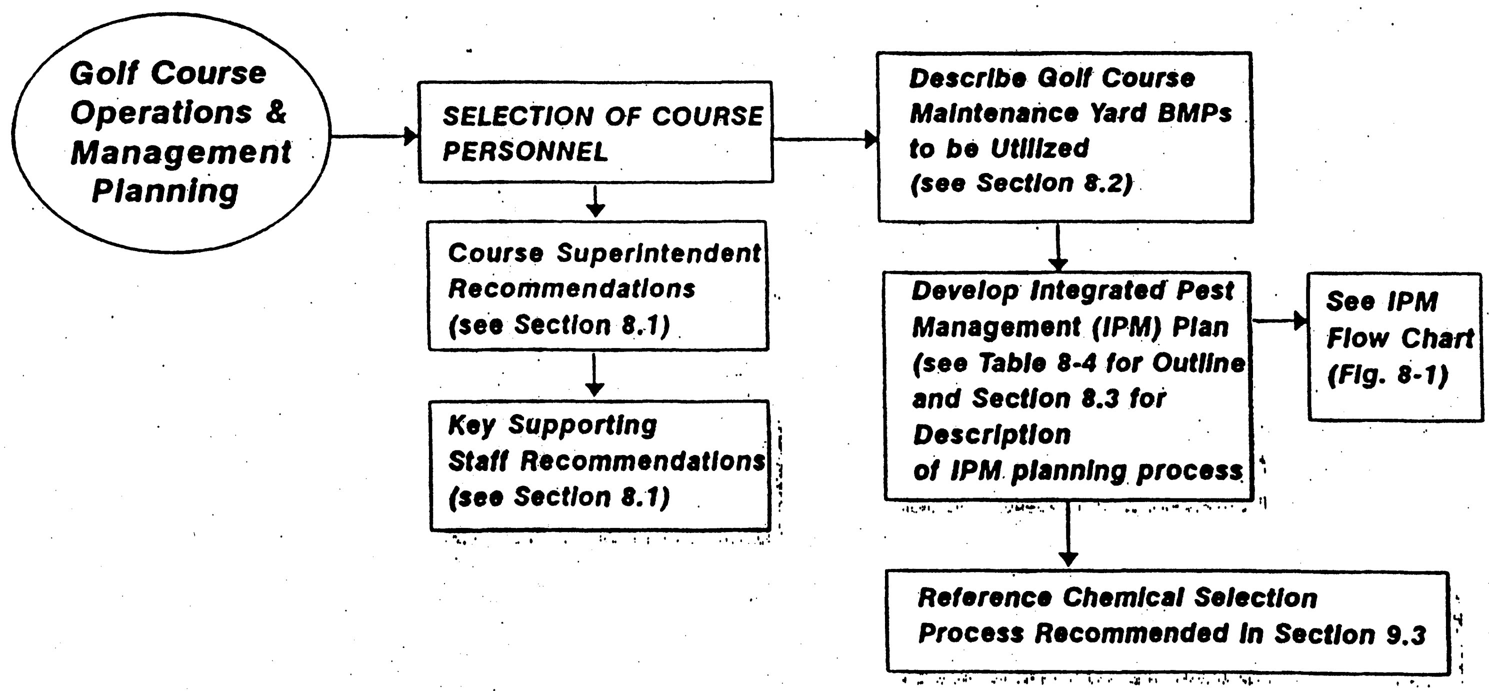
Most work on runoff generation mechanisms in the Pacific Northwest has been conducted on forested catchments. No comparable work has been done for runoff from grasslands. Consequently, the relative importance of macropore flow versus pre-event water (or some other mechanism) in generating storm runoff from golf courses is unknown. Basic research is needed to establish what runoff mechanisms are important from grasslands and under what conditions.

Although both macropore and pre-event theories can explain the relatively fast response observed in stream discharge hydrographs to large storm events, they have widely different implications for impacts to water quality entering streams and wetlands. If macropore theory is correct, then the water entering streams and wetlands during and immediately after the storm event has been in the ground only one day, and attenuation of soluble fertilizers or pesticides would be limited. However, if pre-event theory is correct, water entering streams and wetlands during a storm event is dominated by water that has been in the subsurface for a week to several weeks. Significant attenuation of pollutants would be achieved prior to discharge to surface waters. Both theories have been used in the pesticide selection process described in Section 9.3 of this manual (macropore being the 280 feet/day conductivity and pre-event being the 28 feet/day conductivity, and the difference in chemical selection recommendations is significant.

One of the most important BMPs for golf course design may be retaining a depth to till that will keep interflow, rather than surface runoff, the main water transport mechanism. If the macropore theory is correct, the value of this technique as a BMP relative to agrichemical transport is lessened considerably. If the pre-event theory is correct, the value of depth to till as a BMP criterion for course design cannot be overstated.

Additional research should be conducted to evaluate the merits of these theories. The research should include analysis of laboratory models and field monitoring of controlled test plots. Studies should be directed by a hydrogeologist familiar with groundwater flow theory and equations.

CHAPTER 8 - Maintenance & Operations



Water Quality and Management Chemical Selection

Summary of Best Management Practices

- Define the purpose and goals of the golf course, and the expectations for course quality.
- Staff the golf course with environmentally responsible, educated people.
- Implement an environmentally conscious perspective during all maintenance activities.
- Utilize appropriate turfgrass types and coordinate appropriate cultural practices.
- Use pesticides and other hazardous materials in accordance with an Integrated Pest Management Plan.
- Prepare a contingency plan to deal with pesticide or hazardous material emergencies.
- Coordinate best management practices, such as integrated pest management, centrally-control irrigation, and objective fertilization.
- Keep accurate records.
- Maintain continuing education for supervisory staff.
- Design the maintenance/operations yard in conformance with all OSHA and Washington State Department of Ecology technical manual requirements for storage and use of hazardous materials.

8.0 Turfgrass Maintenance And Operations

In terms of turfgrass maintenance, BMPs may be defined as a direction or focus of management intended to reduce overall environmental deterioration, especially with reference to water quality. Central to the concept are continuing education and technical research aimed at better understanding of interactions between maintenance practices and the environment. Key to successfully implementing the concept in the real world is the attitude of the management staff towards performing BMP related functions.

This section is intended to offer both applicants and reviewers a framework from which to better understand some of what is involved in modern turfgrass maintenance, and enable both parties to prepare or evaluate golf course plans incorporating up to date BMP procedures for environmental protection. This manual does not purport to supplant or replace course superintendent education or experience. It describes specific management areas to be considered, describes certain accepted cultural practices, discusses key management personnel and also discusses issues related to modern management facilities, all with reference to environmental protection. It is not intended as a specific golf course management plan for applicants, as management plans must be highly specific to each project. Management plans must also be dynamic in nature, having the inherent flexibility to evolve with the needs of the course.

Part of the overall golf course management plan may be an integrated pest management (IPM) plan. This chapter provides an example of the elements necessary to define an effective IPM that includes turf grass maintenance and golf course operations (see Table 8-4 at the end of this chapter). This IPM outline should be used as a guide for planning golf operations and maintenance. An IPM decision analysis flowchart is provided in Figure 8-1.

8.1 Course Management and Staffing

Golf course management can be defined as the range of activities by which a golf course is governed or controlled. The responsibility to make appropriate, informed decisions relative to most maintenance considerations rests with the golf course superintendent. Hence, the superintendent must be well educated in turfgrass maintenance, and should be able to document this education and related experience. He or she should also possess the appropriate pesticide applicators license. The superintendent should be computer literate, have the ability to communicate effectively both verbally and in writing, have a great deal of prior turfgrass maintenance experience and a credible work history and must keep informed on new trends in the industry. In order to successfully implement a BMP philosophy, the superintendent must also be environmentally conscious. A certification program for superintendents is offered through the Golf Course Superintendents' Association of America. The program requires continuing education of superintendents. (Note: Courses on turfgrass management are taught at local colleges and universities.)

The duties and responsibilities of the superintendent usually include assuming responsibility for the entire golf course maintenance operation. This can include maintaining the turfgrass and ornamental plants, setting the course up for play, producing the maintenance budget, managing employees, managing and maintaining turf maintenance equipment, and implementing special projects. The superintendent is also charged with purchasing and safely applying or storing pesticides and fertilizers, and regulating course related water use. Thus, the superintendent is often responsible for maintaining the integrity of both the local and adjacent environments, and protecting the safety of employees, patrons and neighbors. A philosophy attuned to BMPs is essential to living up to those responsibilities.

Other key personnel positions support the superintendent. The superintendent's working assistant is usually charged with running the maintenance crew on a day to day basis. He or she may also be charged with performing many of the superintendent's functions, but responsibility always rests with the superintendent. Thus, the assistant should possess the same qualifications as the superintendent, but with more limited experience.

Another key position is the mechanic. The mechanic is typically charged with maintaining the turf management equipment. He or she must be well versed in appropriate areas and must also keep current on industry trends. The mechanic may also be charged with maintaining the shop complex. This often means maintaining the fuel depot, the equipment wash bay, the storage of hazardous waste such as oil and coolant, maintaining appropriate regulatory required policies, record keeping, and performing other important duties.

Other key positions include the irrigation technician and the pesticide applicator. The irrigation technician is charged with maintaining the irrigation system and regulating its use on a daily basis. He or she is often responsible for regulating course water use and should be experienced in system installation, design, control and auditing. The pesticide applicator is typically responsible for the handling, mixing, and subsequent application of all pesticides, and should possess a pesticide applicators license from the State of Washington.

Finally, the equipment operators, laborers, and other crew members must also accept responsibility for protecting the environment. Often times they are the ones actually fueling equipment, washing equipment, applying fertilizers, and making some management decisions. The superintendent should make every effort to obtain intelligent, thoughtful people for these positions.

In summary, all people working on the golf course must understand and accept responsibility for environmental protection in some fashion. Unless there is a total commitment towards that end there may be some elements of risk that cannot be overcome. The people maintaining the golf course, and most importantly their collective attitudes, are probably the single most important determinant in protecting the environment from the effects of maintaining high quality turfgrass.

8.2 Course Operations and Maintenance Yard

Note: Recommendations in this section are general and not exhaustive. Both the King County Surface Water Design Manual and the Washington Department of Ecology Stormwater Management Manual should be reviewed for source control BMPs.

The maintenance area is the central location at which equipment is stored and serviced, fertilizers and pesticides are stored and mixed, fuel is stored, and where employees and managers congregate. Provisions of the Ecology Technical Manual for storage and use of hazardous materials should be employed throughout the course operations yard. These BMPs are not thoroughly covered in this brief review section.

The typical size of a maintenance yard at an 18 hole facility is 1.5 to 2.5 acres. Larger course developments may require greater area or satellite facilities. The maintenance building itself is typically 10,000 to 12,000 square feet, with 7,500 to 10,000 square feet devoted to equipment storage. There can be many variations on the building configuration. c

Pesticide Storage

The pesticide storage facility should be a separate structure (about 200 to 500 square feet) with containment and recovery facilities. Commercial containment flooring and recovery systems are available to prevent pesticides spilled within the storage building from escaping to the outside environment. The pesticide storage room should not have a floor drain. Pesticide spill response kits should be located in the building. The operator should also design and implement a spill contingency plan. Appropriate employees should be well versed in the plan. Personal protective equipment should not be stored in the same room as pesticides, but may be stored in the same structure. Rules regarding secondary containment requirements for facilities where pesticides are stored in bulk quantities are currently being reviewed, and may be in effect in 1993.

The storage building should be located away from employee work areas, and should have limited access. If highly toxic pesticides are stored within the building, exterior posting of the structure is required. The building should contain adequate ventilation and stable storage shelving. It should also be adequately lit, free from clutter, and as fireproof as is technically possible. Fire extinguishers should be kept close by. The local fire department should be notified as to the types of hazardous materials kept in inventory. Keeping up to date inventory records is required by law in most places.

To prevent cross-contamination in the event of an unattended leak, liquids should never be stored above dry, bagged materials. It is also a good idea to separate insecticides, herbicides, fungicides, etc. within the storage area. Highly toxic pesticides must be locked in a secure storage room when unattended, although it is good practice to keep all unattended pesticides in a locked area.

Pesticide Mixing

The area used for mixing pesticides should not be used for any other activities. It should be located close to the storage building, and should be roofed, if possible. Spill response kits should be required adjacent to the mixing area. This area should have limited access and should be situated well away from general work areas.

The mixing area should have pesticide containment and recovery capabilities. Rules that would require containment provisions at mixing/loading areas are currently being reviewed, and could be in effect in 1993. Applicable requirements would depend on the amount of pesticide active ingredients mixed at a permanent facility during a calendar year.

Spilled pesticides do not always have to be disposed of off-site. If the pesticide can be recovered in a usable form (most likely possible if the pesticide is granular), the pesticide should be used according to the instructions on the label. This may drastically reduce the accumulation of dangerous wastes that require proper off-site disposal, which is expensive, highly regulated, and may present future liabilities.

Fertilizer Storage

The fertilizer storage area should be well ventilated and dry. It should be away from general work areas, have limited access and be fireproof, if possible. A running inventory of stored fertilizers should be maintained. The proposed containment rules discussed under Pesticide Storage and Mixing, above, would also require secondary containment for fertilizers when the amount stored exceeds a designated threshold.

Equipment Wash Bay

An area for cleaning equipment (about 400 to 500 square feet) should be designated and properly equipped. Cleaning of equipment can potentially release oil and/or grease into drainage water. Recycling stations that remove these contaminants from water are commercially available, and could be installed in the wash bay.

Equipment Storage and Maintenance

A specific area (about 10,000 square feet total) should be designated for equipment storage and maintenance. The equipment storage area and the mechanic's shop should be configured to prevent the accidental release of oil, grease, hydraulic fluid, gasoline, or coolant directly from the equipment. Drainage should be controlled and directed to a vault for off-site disposal. Oil changing and changing of brake fluids, battery fluids, coolants and other wastes should occur inside a maintenance garage. Recycling of all possible materials should occur. Spill cleanup materials must be on hand.

Fuel Depot

A specific area should be designated for dispensing fuels. Modern facilities have been moving away from underground storage tanks, and are using above-ground fuel containment. All fueling must occur under a roof and be protected from precipitation. Fueling areas must be paved with Portland cement and should be designed so that stormwater will not flow onto the fueling pad. Fire extinguishers and spill cleanup materials should be readily available at the fueling site. Drainage should be controlled and directed to a vault for off-site disposal or to a process treatment system.

Hazardous Waste Storage

An area with limited access should be designated for the storage of hazardous wastes (such as used oil, used coolant, and old batteries). Self-contained hazardous waste bins are commercially available. Drainage should be controlled and directed to a vault for off-site disposal.

Composting Area

A large volume of compostable solid waste (such as grass clippings) is typically generated on a golf course. The maintenance facility should be equipped to deal with this waste. This could be accomplished by establishing a composting facility near the yard. This would allow clippings and other debris to be recycled without contributing to landfill problems. The composting facility should be downwind from residential areas, lined to prevent leaching, and covered to prevent inundation from rain.

8.3 Integrated Pest Management and Related BMPs

Definition of the Integrated Pest Management Strategy

Integrated Pest Management (IPM) involves limiting pest populations to sufficiently low thresholds to avoid economic damage to course operations by using combined and balanced strategies of biological, cultural, genetic, chemical and other control technologies. Establishment of control area boundaries, pest tolerance thresholds and use of pest population prediction tools are critical to the overall IPM strategy (see Figure 8-1).

IPM does not advocate eradication of pest populations. Integrated pest management favors suppression of the pest to the level that damage caused by the pest is acceptable in both an economic and aesthetic sense. The IPM concept favors and emphasizes natural pest manipulation but does not exclude chemical manipulation. It is a concept that utilizes integrated cultural, biological, and chemical pest control strategies. IPM seeks to help avoid adverse environmental impacts and injuries to non-target entities which may arise from traditional chemical pest eradication procedures.

Although IPM systems need to be flexible and broad, a generalized approach can be described by the following steps (Washington State University 1991):

1. Identification of pests, including methods to obtain diagnosis, incidence and loss information.

2. Definition of the management unit.

3. Development of an optimum pest management strategy coordinating multiple and responding to varying season and weather conditions.

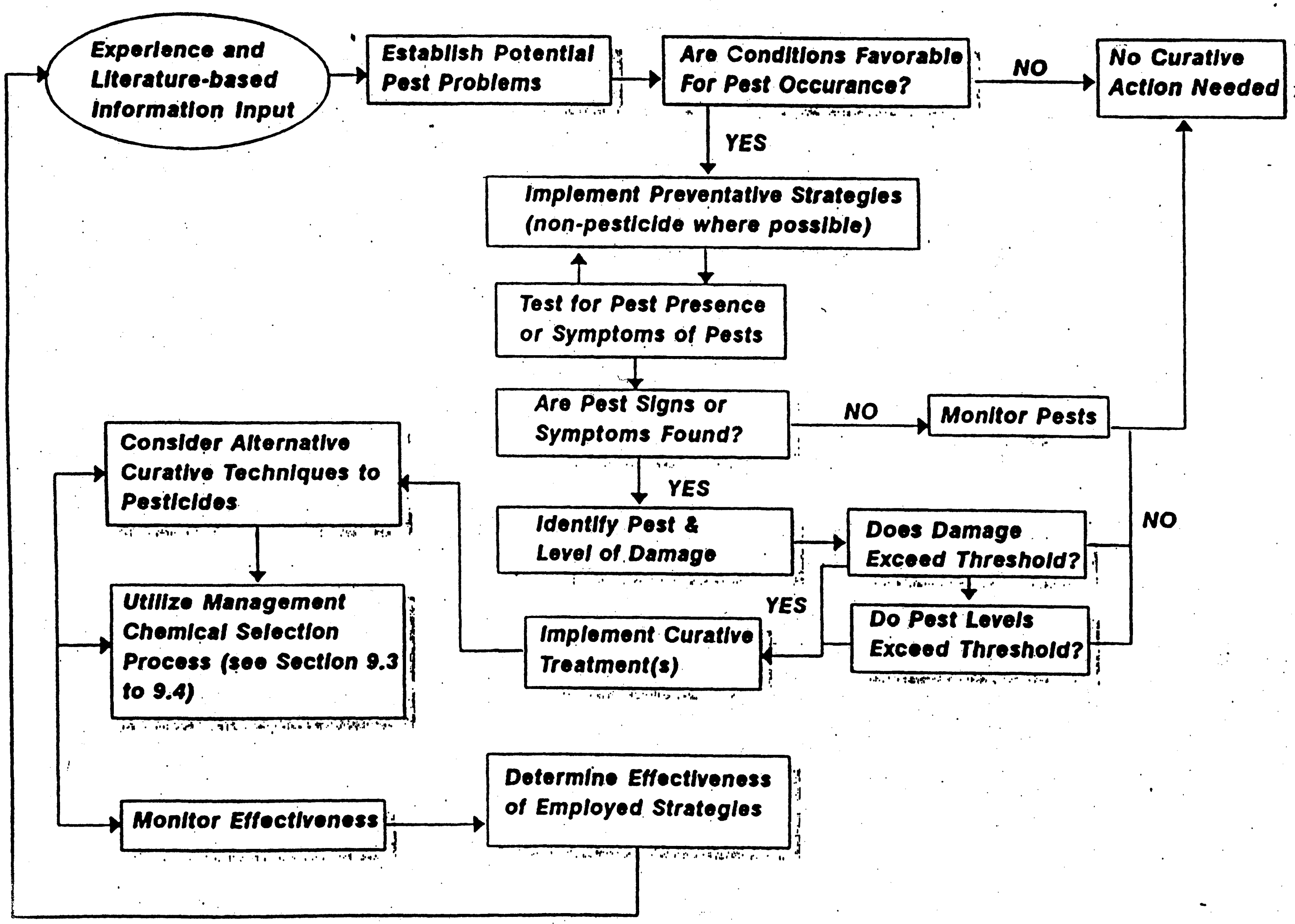
4. Development of reliable pest monitoring techniques.

5. Determination of pest damage or injury tolerance thresholds and establishing pest levels to damage levels.

6. Development or identification of descriptive or predictive models for timing pest, timing pesticide applications, identifying knowledge gaps and strategizing control.

The main objectives of an IPM strategy are to: (1) utilize effective monitoring to enable more intelligent control of pest populations; (2) minimize or more logically allocate pesticide use while optimizing pesticide efficacy; and (3) improve turf grass quality and lower operating costs.

Figure 8-1. Integrated Pest Management Plan Decision Flow Chart Example.



During the fall of 1990, Beak Consultants, Inc. conducted a golf course survey to determine working golf course management practices in the Puget Sound Region (survey summary and results are listed in Appendix C). These results may be useful to development of IPM plans by developers of new courses.

Turfgrass IPM Planning

The following is a recommended approach to developing a turfgrass IPM plan.

Delineating the Management Area

Ten specific turfgrass management areas exist (Table 8-1). Selecting the appropriate genetic variety and type of plant materials for each area is of the utmost importance.

Initial Information Gathering

Background information should be compiled on potential pests and non-target entities. Such information would include identification of species, documenting life cycles, finding appropriate cultural and biological controls, finding applicable chemical controls, documenting prior pest pressure histories, documenting prior records of successful and unsuccessful pest control, and obtaining any other applicable information which contributes to the knowledge base. This also includes gathering background information on each particular management area, such as soil type, plant type and projected cultural practices. Good sources of information are area course superintendents and the Washington State University Cooperative Extension Service (see Section 10.3 for a publication list).

Monitoring Pests and Non-Target Entities

Monitoring includes making frequent observations on which organisms are present within the management area, to what extent they are present, where they are, and how active they are in that area. The populations and activities of pests versus non-target species, as well as of pests versus control entities (i.e., predators), can have a significant impact on IPM plan implementation.

Monitoring and plant disease detection is easier with the use of ELISA diagnostic kits and pest prediction models, but such kits and models are not critical to IPM implementation. To date, verified test kits and models are not available for turf pests or diseases typical in the Pacific Northwest. ELISA is an acronym for enzyme linked immunoassays. It is the same technology that brought home pregnancy kits in the marketplace. An antibody specific to the plant disease is created using serology. When those antibodies (found in the plant sample) are released they trigger an indicator, such as a dye. When the indicator turns color, there is evidence of the presence of specific plant pathogens.

Table 8-1. Designation of Turfgrass Management Areas and Turfgrass Types on a Typical Cool Season Golf Course

Management Area	Appropriate Turfgrass Types*
Green Surface	Creeping Bentgrass (Providence, Putter, Penncross, Pennlinks, SR-1020, Cobra Varieties)
Collar	Creeping Bentgrass
Green Surround	Turftype Perennial Ryegrass/Creeping Red Fescue Mixture
Approach	Turftype Perennial Ryegrass/Creeping Red Fescue/Colonial Bentgrass or Creeping Bentgrass
Tee Surface	Turftype Perennial Ryegrass or Creeping Bentgrass or mixtures of Perennial Ryegrass and Creeping Bentgrass
Tee Surround	Turftype Perennial Ryegrass, Creeping Bentgrass or Creeping Red Fescue Mixtures
Fairway	Turftype Perennial Ryegrass/Colonial Bentgrass/Creeping Red Fescue/Hard Fescue or Kentucky Bluegrass mixtures
Rough	Creeping Red Fescue, Chewings Fescue, Hard Fescue, Colonial Bentgrass and Turftype Perennial Ryegrass
Amenity Turf	Creeping Red Fescue, Chewings Fescue, Hard Fescue, Colonial Bentgrass and Turftype Perennial Ryegrass
Ornamental Lawn	Improved Turftype Perennial Ryegrass and Red Creeping Fescue or Colonial Bentgrass

Note: The relative level of cultural intensity and the relative level of pesticide input for these areas in general is detailed in Table 8-2, below.

* From R.L. Goss, S.E. Brauen, W.J. Johnston, T.W. Cook, and R.D. Ensign. Turfgrass Seeding Recommendations for the Pacific Northwest. PNW 299. Washington State University Cooperative Extension, Pullman, WA.

Table 8-2. Turfgrass Management Area Matrix. (This array describes the relative level of cultural intensity for specific cool season turfgrass sections on an average golf course.)

	Modified Soil	Percent of Area*	Auxiliary Drainage	Fertilizer Requirement	Irrigation Requirement**	Mowing Frequency	Cultivation Frequency
Greens Surface	yes	2	yes	high	medium	high	high
Collar	yes	<1	yes	high	medium	high	high
Green Surround	no	3	no	medium	medium	medium	medium
Approach	no	<1	yes/no	medium	medium	high	high
Tee Surface	yes	2	yes/no	high	medium	high	high
Tee Surround	no	2	no	medium	medium	medium	medium
Fairway	no	40	yes/no	medium	medium	high	high
Rough	no	45	no	low	low	low	low
Amenity Turf	no	5	no	low	low	low	low
Ornamental Lawn	no	<1	no	high	medim	high	low

* Denotes the estimated average percent of turfed area occupied by that section. Actual percentage will vary according to course design.

** Irrigation requirements will vary depending on soil types. Coarse textured soils low in organic matter need more irrigation relative to fine textured soils.

Establishing Economic Damage Thresholds

Management areas will have differing levels of acceptable pest damage. For example, greens are expected to support turfgrass of higher quality than rough areas. For that reason, damage from pest pressure becomes unacceptable at much lower levels. Setting of economic damage thresholds for specific areas will be somewhat subjective and determined by the course superintendent.

Establishing Action Levels

A correlation should be established between the pest population level, along with other variables such as weather or cultural practices, and the degree of injury deemed unacceptable from that pest. This procedure often takes a long time. Action levels have been poorly established for many turfgrass pests; more precise models for prediction of turf diseases are under development (Vargas et al. 1989). Most turfgrass diseases are a function of environmental conditions when the host species and the pathogen are both present. Mathematical models can be used to predict disease occurrence based on some combination of air temperature, soil temperature, soil moisture, leaf wetness and relative humidity. All models require calibration to local conditions via correlation to disease outbreaks. Models for Pythium blight (a fungus), anthracnose (a fungus) and annual bluegrass seedhead emergence have all been developed (Vargas et al. 1989). Before use, verification of the applicability of such models to conditions on a specific course must be established. Use of these models can avoid prophylactic treatment for diseases known to be inconsistent in appearance. The anthracnose model is reported to have a 95 percent accuracy rate in predicting outbreaks over six years of field testing (Vargas et al., 1989); however, this has not been demonstrated for the regional climate of the Pacific Northwest.

Establishing Effective Treatments

Not every pest will be suppressed using biological or cultural treatments. One of the most important parts of this phase involves targeting which pests can be suppressed effectively with biological, cultural, or chemical treatments, and those which cannot. Also very important is knowing which beneficial entities are impacted by treatments, and to what degree. Generally speaking, the ideal direction behind implementing effective treatment strategies involves mixing tactics which are most effective against the target, least disruptive to non-targets, and produce the least impact to the environment.

Biological management of soil-borne diseases has been reported through the use of applied microbes. The two mechanisms of control are competition by the applied microbes for nutrients required by the pathogen and the production of beneficial substances antagonistic to the germination or growth of pathogens (Vargas et al. 1989). Biological control can occur by either adding the beneficial microbial population or altering the thatch or soil to promote their natural growth. As an example, for necrotic ring spot disease, caused by *Leptosphaeria korrae*, a product named Soil Aid (Agro-Chem Corporation of Franklin Park, Illinois) is an enzymatic wetting agent designed to flush thatch and soil of substances inhibiting high microbial activity. That treatment is followed by treatment with products such as Green Magic, Strengthen or Renew which contain nutrients and plant and microorganism extractions shown to reduce the growth of L. korrae (Vargas et al. 1989). Alternatively, Lawn Restore is a product (Ringer Corporation, Minneapolis, Minnesota) comprised of bone meal, feather meal, soybean meal and other proteins supplemented with Actinomycete fungi and bacteria in the genus Bacillus. These microorganisms have been shown to produce substances inhibitory to L. korrae (Vargas et al. 1989). To be effective, either of these strategies must be applied on a regular basis, either monthly or bi-monthly, throughout the growing season. As a second example of biological control, *Poa annua*, considered a weed in turfgrass stands, has been only poorly controlled with pre-emergent (for the annual variety) or post-emergent (for the perennial variety) herbicides. In addition, the post-emergent arsenical herbicides are highly toxic. As an alternative treatment, the bacterium *Xanthomonas campestris* has been shown in the laboratory to interfere with uptake of water and nutrients by P. annua and is also very specific to that species alone. Course supervisors should stay informed of these and similar alternative strategies and determine their effectiveness and applicability for King County courses.

Evaluating Treatment Efficacy

Evaluation of treatment efficacy in impacting the target and bypassing non-targets must feed information back into the dynamic IPM process (see Figure 8-1).

Record Keeping

Record keeping is one of the single most important phases in IPM. While important for the site manager, it is probably more important for the site manager's successor. If a new site manager has to repeat the entire IPM development process, its purpose is essentially defeated.

Turfgrass Pesticides

Pesticides can be defined as synthetic or naturally occurring substances which are used to suppress or eradicate pests. Their use should be considered as indicated in the IPM decision analysis flowchart (see Figure 8-1). There are several types of pesticides appropriate for use on turfgrass, usually specific to the category of pest to be controlled. There are also several guidelines appropriate for using pesticides (see Appendix E). Environmental concerns should be addressed as indicated in Chapter 9. All local, state and federal guidelines and/or regulations pertaining to pesticides must be followed. Prior to using any pesticide, read the label. Pesticide distribution, storage and use is regulated by the Washington State Department of Agriculture. Golf course superintendents should be familiar with RCW 15.58, the Pesticide Control Act: RCW 17.21, the Pesticide Application Act; and WAC 16-288, Roles Relating to General Pesticide Use.

Table 8-3. Major Nitrogen Carriers Available for Use in Turfgrass Management Schemes
(Blends and specific formulations are available to suit specific needs.)

Carrier	Class*	Analysis**	Release Rate	Temperature Release Dependence	Water Solubility
Ammonium Nitrate	Inorganic	31-0-0	Quick	Low	High
Ammonium Sulfate	Inorganic	21-0-0	Quick	Low	High
Calcium Nitrate	Inorganic	15-0-0	Quick	Low	High
Urea	Organic	46-0-0	Quick	Low	High
Ureaformaldehyde	Organic	38-0-0	Medium	High	Medium
IBDU	Organic	31-0-0	Medium	Medium	Medium
Methylane Urea	Organic	40-0-0	Medium	High	Medium
Sulfur-coated Urea	Coated	32-0-0	Medium	Medium	Low
Resin-coated Urea	Coated	20-0-0	Medium	High	Low
Resin-coated Ammonium Sulfate	Coated	20-0-0	Medium	High	Low
Sewage Sludge	Natural	6-2-4	Slow	High	Low
Protein Waste	Natural	10-3-4	Slow	High	Low

* Carrier classes technically are synthetic-inorganic, synthetic-organic, synthetic-organic coated, and natural-organic.
** Analysis can vary somewhat depending on formulation.

Adapted from Beard, 1982.

Economic damage threshold and action level criteria should determine the need for pesticide use. Economic damage thresholds are set by the user, and are dependent on the expected level of maintained quality. Action levels are set by the pest, but only site specific experience and frequent monitoring allow the user to know when action levels have been exceeded. The turf manager must decide how much pest damage is acceptable on any given area for any given time, then act accordingly.

Pesticide selection must consider how effective the pesticide is towards the intended target versus threat to the environment or non-targets. In selecting a pesticide it is absolutely essential that the user select materials specifically labeled for the use at hand. Using pesticides in contradiction to label instructions is a violation of law and should never be tolerated (see Appendix E).

It is essential that the user properly formulate the pesticide solution to be applied specifically according to label directions. Most pesticide spills occur during the mixing phase. Thus, it is important that the pesticide be formulated in an area that can be contained and cleaned up in the event of a spill (see Section 8.2, Pesticide Mixing discussion). Pesticide spills must not be allowed to escape into the open environment. Pesticide spill containment is made easier by using spill response kits. These kits or stations (larger versions) contain several items necessary for containment and clean-up of spills, including highly absorbent materials, gloves, coveralls, boots and spill disposal bags.

All application devices must be properly calibrated. Some modern pesticide sprayers are equipped with flow control computers that regulate the amount of pesticide output relative to ground speed. This ensures that the correct amount of material is being delivered regardless of variations in speed or changes in terrain. The actual rate of material applied must be dictated strictly by the label instructions. The user must also ensure that the pesticide is applied only to the intended target area. Consideration must be given to weather and local environmental conditions. Spray boom shrouds can help by preventing wind related drift of spray. It should also be emphasized that anyone applying pesticides should possess a pesticide applicators license, which entails a pointed educational process. Precise records indicating how much of which material was applied are required by the Washington State Department of Agriculture (Form AGR 4235). Turfgrass management software is available to facilitate record keeping procedures.

Best Management Practices for pesticide application include the following (Balogh and Walker, 1992):

- Appropriate training in the use of pesticides, and in pesticide application techniques.

- Proper maintenance and precise calibration of application equipment, to ensure precise distribution at the intended rate. Pesticide rate use should be determined by label instructions.

- Consideration of the timing of pesticide application relative to precipitation events or rainfall.

- Maintenance of a buffer between water bodies or non-target zones and application zones, which increases the transport distance and decreases the potential for contamination.

- Selection of a pesticide must be based on education and experience. Additionally, the user should consider efficacy of treatment and the criteria that reduce off-site movement and potential adverse impacts.

- Pesticide containers must be properly disposed. This will reduce the threat of non-target exposure.

Turfgrass Fertilizers

Fertilizers are materials which carry, or are partially composed of, essential nutrients such as nitrogen (N), potassium (K), and phosphorus (P). These are the major elements required by turfgrasses. They are essential for protein synthesis, cellular energy functions, and catalytic functions. Nitrogen is the element applied in the greatest quantity. Fertilizers are also formulated to carry other nutrients such as calcium (Ca), magnesium (Mg), sulfur (S), boron (B), manganese (Mn), and a host of others. These elements are not required to the degree of the major elements are, but they are essential.

Many types of nitrogen carriers utilizing several nitrogen sources are commercially available. The basic nitrogen carriers in turfgrass management schemes are inorganic ions such as nitrate and ammonium. With these types of carriers nitrogen is considered quickly available due to solubility properties. Other carriers are synthetic organic molecules, such as urea and its associated derivatives. Nitrogen contained by these carriers is either quickly available or slowly available, depending on the molecular formulation. A third category of carriers is natural organic material such as protein waste or sewage sludge. These kinds of carriers provide nitrogen that is slowly available. Certain nutrient carriers can also be coated or encapsulated to provide highly specific nutrient release characteristics. Coatings tend to be either sulfur, or some form of synthetic resin or plastic. The advantage in using coated carriers is in knowing the detailed specifics of nutrient release rates. They are generally considered slow release carriers.

Quick release sources of nitrogen, especially nitrates, are readily leached from the soil depending on the intensity of rainfall or irrigation, and other cultural practices. For that reason, slow release nitrogen carriers have received a great deal of environmental attention. Using slow release or slowly soluble carriers helps to prevent nitrogen losses due to leaching or volatilization. On the other hand, these carriers can be subject to displacement and run-off in certain situations. An additional problem with using slow release carriers is the accumulation of residual nitrogen reserves. Slow release carriers generally cost more per unit nutrient than quick release carriers.

In general, highly maintained turfgrass areas such as greens, tees, and fairways should receive combinations of both quickly available and slowly available nitrogen. The current trend for fine turf is to utilize slow release forms for sustained, long term supply of nitrogen, supplementing the turf as needed with quickly available carriers at very light rates. Using very light rates helps to prevent nitrogen losses due to leaching, provided irrigation events are appropriately timed. In theory, the practice is aimed at providing only the amount of nitrogen that can be taken up by the plant at a given time. Light rates of application vary from 0.5 to 0.03 pounds of actual nitrogen per 1,000 square feet. Lesser maintained areas, such as roughs, can usually get by on the slowly available forms. A high quality golf course cannot utilize only slow release forms of nitrogen.

Local golf course research has shown ammonium sulfate to be superior to other organic nitrogen sources for establishing bentgrass greens (Nus et.al, 1985). Ammonium nitrate and ureaformaldehyde were worst. Surprisingly, IBDU-treated plots showed the greatest nitrate leaching. Ammonium sulfate treated plots had the least leaching. This is contrary to prevailing assumptions, and more data should be gathered (Nus, et.al, 1985).

The actual amount of nitrogen needed for any given area depends on many factors, including the specific turf types present, the level of traffic or other stresses imposed on the turf, the type of carrier utilized, the age of the turf, the specific soil type, the level of applied irrigation, climactic patterns, nutrient loading from irrigation, and the specific purpose for which the nitrogen is applied. Timing the application depends on specific growth patterns of the turf, and experience. When applying any nutrient in any form, it is important that the application device be properly calibrated to deliver a precise amount or volume.

Local fertilization research with lysimeters to determine leachate loss has developed the following recommendations (Brauen, et.al, 1992):

- Use moderate rather than high fertilizer amounts;
- Apply nitrogen at higher frequencies in lower concentrations than has typically been used;
- Use peat-modified sand rooting material rather than pure sand under greens; and,
- Use a careful selection of combined slow-release and soluble nitrogen sources during the cool wet season.

Regarding nutrients other than nitrogen, the quantity applied and the timing of the application should be dictated by both soil testing and plant tissue testing. The testing involves analyzing soils and turfgrass clippings for nutrient content.

Establishing baseline nutrient information for each specific area of turfgrass is critical. Soil and tissue sampling (during the growing season) for the first year or two could be considered a reasonable start for establishing a baseline.

Table 8-4. Outline of IPM Plan, Including Turfgrass Management and Golf Course Operations Planning.

I) MANAGEMENT AREAS OF A GOLF COURSE
- A) Management Defined
  - 1) Turfed Areas
    - a) Green Surfaces
    - b) Collars
    - c) Green Surrounds
    - d) Tees
    - e) Tee Surrounds
    - f) Fairways
    - g) Roughs
    - h) Amenity Turf
    - i) Ornamental Lawns
  - 2) Non-turfed Areas
    - a) Bunkers
    - b) Constructed Ponds or Lakes
    - c) Constructed Creeks or Streams
    - d) Constructed Wetlands
    - e) Ornamental Plantings
  - 3) Natural Areas

II) TURFGRASS MAINTENANCE CONSIDERATIONS
- A) Timing of Development
- B) Appropriate Turfgrasses
- C) Cultural Practices
- D) Needed Equipment
- E) Irrigation Source
- F) Management Budget
- G) Labor Considerations
- H) Intended User
- I) Style and Design
- J) Purpose and Goals
- K) Quality Expectations
  - 1) Dependence on Purpose and Goals
  - 2) Relation to Other Considerations
  - 3) Relationship to Planning

III) KEY MAINTENANCE PERSONNEL AND RESPONSIBILITIES
- A) Key Personnel
  - 1) Golf Course Superintendent
    - a) Education
    - b) Communication
    - c) Experience
    - d) Goals
    - e) Decisions
    - f) Attitude
  - 2) Superintendent Responsibilities
  - 3) Support Staff
    - a) Assistant Superintendent
    - b) Mechanic
    - c) Irrigation Technician
    - d) Pesticide Applicator
    - e) Equipment Operators
    - f) Laborers

VII) INTEGRATED PEST MANAGEMENT
- A) Definition
- B) Philosophy
- C) Goals
- D) Components
  - 1) Area Definition
  - 2) Information Gathering
  - 3) Monitoring
  - 4) Threshold Establishment
  - 5) Action Level Establishment
  - 6) Treatment Establishment
  - 7) Decision Making
  - 8) Treatment Evaluation
  - 9) Record keeping

IV) TURFGRASS PESTICIDES
- A) Definition
- B) Categories
- C) Use guidelines
- D) Management Guidelines
- E) Decisions
  - 1) IPM
- F) Selections
  - 1) Education
  - 2) Experience
- G) Formulation
  - 1) Handling

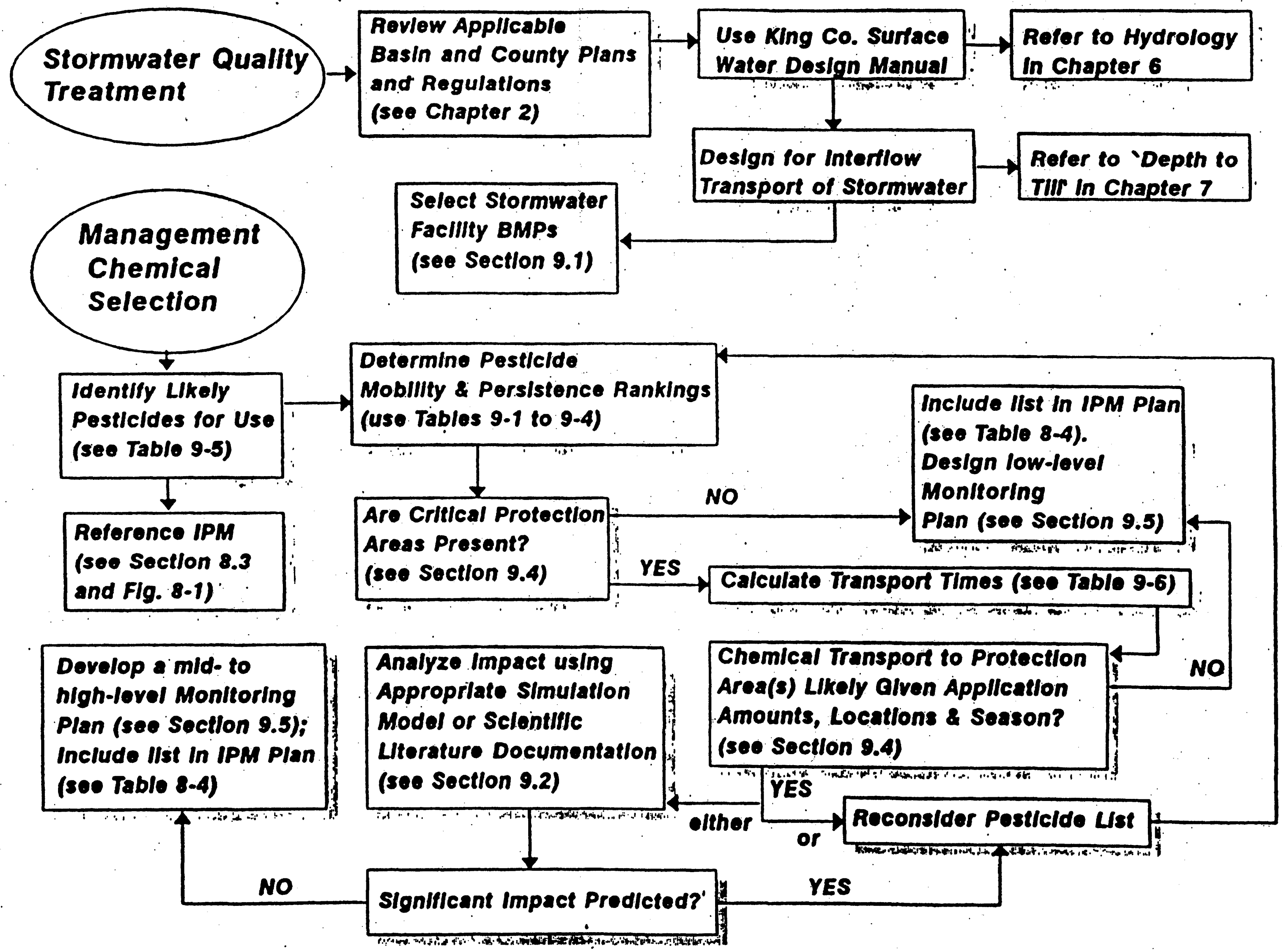
- H) Application
  - 1) Factors
  - 2) Labels
- I) Records
- J) Fate
  - 1) Factors
- K) Storage
- L) Mixing Area

III) IRRIGATION RELATED CONCERNS
- A) Irrigation source
  - 1) Groundwater
  - 2) Surface water
  - 3) Wastewater
    - a) Effluent as a Source
- B) Irrigation Water Quality
  - 1) Nutrient Loading
  - 2) Salts
  - 3) Contaminants
- C) Sustainable Yield
  - 1) Use Rates
  - 2) Need Determinations
  - 3) Minimization Features
- D) Irrigation System
  - 1) Computers
    - a) Scheduling
    - b) Flow Management
  - 2) Design

V) TURFGRASS FERTILIZERS
- A) Carriers
  - 1) Nitrogen
    - a) Quick Release
    - b) Slow Release
    - c) Concerns
    - d) Rates
    - e) Application
- B) Other Nutrients
  - 1) Soil Tests
  - 2) Tissue Tests
- C) Fate Of Nitrogen
- D) Fertilizer Storage

VIII) TURFGRASS MAINTENANCE FACILITY
- A) General Aspects
  - 1) Sizing
- B) Equipment Wash Bay
- C) Equipment Storage
- D) Fuel Depot
- E) Hazardous Waste
- F) Solid Waste
  - 1) Composting

CHAPTER 9 - Water Quality & Management Chemical Selection



Water Quality and Management Chemical Selection

Summary of Best Management Practices

- Use an Integrated Pest Management (IPM) to achieve effective control of applied management chemicals and limit off-site chemical transport. When designing the IPM program, it is important to determine the proper chemical to use, and to employ a computerized irrigation control system.

- Incorporate stormwater quality BMP facilities into course design. These may include infiltration, filtration, wet ponds, biofiltration swales and artificial/constructed wetlands.

- Alternative BMP facilities for surface runoff and water quality control that could be used include: modified sand-peat filters; a combination of wet ponds/sand filters; granular activated charcoal systems (discussed but not recommended); regulated stormwater control systems; and underdrain leachate collection systems.

- Employ simulation models or perform a literature review to estimate impacts if pesticide transport to surface or groundwater resources is likely.

- Ensure proper selection and use of pesticides as determined through application of pesticide mobility and persistence models.

- Prepare a Water Quality Monitoring Program that explicitly defines objectives, establishes monitoring frequency based on estimated transport times, and includes stations or methods for early warning detection. The Program should employ:
  - Staged monitoring.
  - A course management response scenario.
  - Method for establishing baseline monitoring data.
  - Sound statistical methods for analyzing results.
  - Criteria for returning to baseline monitoring or golf course maintenance following a response event.
  - Remedial action criteria to respond to results.

  It is important that the Program outline responsibilities (and funding) for implementing the Monitoring Program and for interpretation of and response to the data.

9.0 Water Quality and Management Chemical Selection

Historically, golf courses have used pesticides and fungicides extensively in the management of tees, greens and fairways. The use of such chemicals, it is now known, may present a threat to both surface and subsurface water quality, and to aquatic resources and drinking water sources. This chapter discusses water quality management and the uses of various chemicals in golf course management. Criteria for evaluating pesticides for use are provided, as is a method for estimating chemical mobility in the natural system. Also provided in this chapter are Best Management Practices that can be followed to reduce the need for, and impact of, chemical applications, additional considerations for special protection areas, methods for analyzing the impact of chemical applications on the natural system, and suggestions for establishing a monitoring program to ensure protection of environmental quality. Many of the issues raised in this Chapter are closely aligned to Integrated Pest Management planning, discussed in detail in Chapter 8.

9.1 Best Management Practices for Protection of Water Quality

Golf course BMPs for protection of water quality can affect decisions related to golf course siting, design, construction, pest management, course maintenance and monitoring. The general goals of implementing BMPs include (Balogh and Walker, 1992):

- Reducing offsite transport of sediment (Chapter 7), nutrients and pesticides;
- Controlling the rate, method, and types of chemicals applied to the golf course;
- Reducing total chemical loads by use of Integrated Pest Management (IPM), economic thresholds, alternative pest control options, and fertility testing (Chapter 8);
- Using both biological and mechanical soil (Chapter 7) and water (Section 5.2) conservation practices (SWCPs); and
- Educating managers and the public on the relationship of environmental issues and systems management (Chapter 8).

Best Management Practices

Integrated Pest Management (IPM)

The Bio-Integral Resource Center (1991) defines IPM as " a decision-making process which considers the whole ecosystem to determine the best methods for controlling pests...The objective of an IPM program is to suppress the pest population below the level that causes economic, aesthetic, or medical injury.

Strategies are designed to require a minimum reliance on pesticides." See Section 8.3 for a description of BMPs employed during an Integrated Pest Management program.

From a surface and shallow groundwater quality control perspective, IPM technologies are key to effective and logical control of applied management chemicals. Secondly, siting courses on soils with medium-texture, high organic matter content, high cation exchange capacity, and low erosion and runoff potential will act to limit chemical transport off-site. The soil thickness should provide a proper thickness to the high ground water table elevation or to the underlying bedrock (see Chapter 7). Chemical selection, as discussed in Section 9.3, is a third key element to protection of water quality. The fourth element is use of a computerized irrigation control system (Section 5.3).

Stormwater Quality BMP Facilities

Storm water runoff may be generated from a golf course and adjacent facilities during heavy rainfall events (See Chapter 6 for a discussion of overland versus interflow). Impervious golf course surfaces include: parking areas, roads, rooftops, sidewalks, patios, cart paths or other impervious features (Klein, 1990). Loadings of various pollutants from developed areas can be high if unmitigated. Developed areas may release 2 to 20 times more nutrients (into an aquatic environment) than a forest or cropland (Klein, 1990) prior to water quality treatment. A major source of storm water pollutants are impervious surfaces subject to motor vehicle use.

Surface runoff from impervious or pervious surfaces should be treated before being released to surface or ground water resources. Proper runoff control and water quality facilities need to be provided. These facilities should be designed to meet County requirements and criteria, as specified in the King County Surface Water Design Manual (1990), and as recommended in Section 6.2.

Infiltration

Infiltration may be provided along a trench or within a basin. Specific infiltration design criteria and requirements are listed in the King County Surface Water Design Manual (1990) and Ecology's Stormwater Management Manual for the Puget Sound Basin (1992). Proper grain size, cation exchange potential and other design characteristics are necessary for infiltration, as is consideration of groundwater aquifers below the infiltration site. Ecology (1992) identifies infiltration as the preferred stormwater management practice for effectively treating runoff and controlling streambank erosion (Ecology 1992). Infiltration sites should be approved by a qualified geologist (see Section 7.4). The following removal efficiencies were cited by Klein (1990):

- metals - 100 percent,
- nitrogen - 80 percent and
- phosphorus - 80 percent.

Filtration

Ecology (1992) recognizes three BMPs using filtration techniques: 1) Sand Filtration Basin, 2) Sand Filtration Trench and 3) an experimental Aquatard System. Filtration is not considered as effective as infiltration BMPs for pollutant removal (Ecology 1992). Sand filtration trenches and basins pass runoff through a sand filter system onto an underdrain before discharge.

Wet Ponds

Specific wet pond design criteria and requirements are listed in the King County Surface Water Design Manual (1990). Wet ponds maintain a dead storage volume of water that offers removal mechanisms for dissolved phosphorus and nitrogen by settling of fine particles, nutrient uptake by algae and fringing vegetation, denitrification, microbial degradation of organics, sequestering of phosphorus and metals in the sediments, and dilution of the first flush input water from any storm with the higher quality retained dead storage water. Wet ponds have been listed as an approved Best Management Practice (BMP) in the Puget Sound Stormwater Manual (Ecology, 1992a) for treatment of storm water. The following removal efficiencies have been cited for wet ponds (Klein, 1990):

- Heavy metals - 40-80 percent,
- Total phosphorus - 40-60 percent,
- Total nitrogen - 40-60 percent.

The King County Surface Water Management Division should be consulted for the results of their sediment and decant disposal study.

Biofiltration swales

Biofiltration swales function by physical filtration, settling of suspended particles and absorbed contaminants, and a degree of uptake and sorption of nutrients and metals by the vegetation itself. Grass lined swales or channels can be very effective at removing sediments, particle-bound toxicants such as metals, and oil and greases from surface runoff. Periodic maintenance is required to remove the sediment that builds up in the swale to avoid a delayed release of most or all of the particles in a later runoff event. Grassy swales are effective at the removal of metals and total suspended solids (TSS) (Metro, 1982). The King County Surface

Water Design Manual recommends a 200-foot length swale with specific controlled depths, flow rates, and design storm treatment capacity. Shorter swales may be used if widened to result in equivalent hydrologic residence time. Grass swale contaminant removal efficiencies are variable and a function of length, water depth, velocity and maintenance, but performance of similar facilities in the Puget Sound region have been summarized by Ecology (1992a) as follows:

- 83 percent reduction of influent total suspended solids,
- 67 percent reduction of lead,
- 46 percent reduction of copper,
- 29 percent reduction of total phosphorus,
- 63 percent of total zinc and total aluminum,
- 30 percent of dissolved zinc, and
- 75 percent reduction in oil and grease/TPH.

It is recommended that swales be combined with roughs wherever possible, which requires a commitment to avoid pesticide application on, or fertilization of, those roughs.

Artificial/Constructed Wetlands

Artificial wetlands are recognized by Ecology (1992) as a BMP for runoff control. The constructed wetland design incorporates shallow marsh areas as well as a permanent pool providing treatment of both conventional pollutants and nutrients (Ecology 1992). Artificial wetlands are designed to function similar to a natural wetland system and incorporate such design features as shallow water areas and vegetation. Artificial wetland systems should be more efficient at microbial or organic compounds than wet ponds, but are more expensive to design, plant and maintain. Design criteria and requirements are specified by Ecology (1992).

Swales, wet ponds and artificial wetlands are all consistent with golf course design strategies for both play and aesthetics.

Additional BMP Facilities for Surface Runoff and Water Quality Control

Modified Sand-Peat Filter

An earth-dike sand-peat filter system designed by John Galli (Metropolitan Washington Council of Governments) is reported to be as effective as other infiltration measures for contaminant removal (Klein, 1990). The system is layered and consists of (bottom to top):

- a 6-inch bed of bank-run gravel (fitted with a perforated underdrain pipe),
- a 24-inch layer of fine-medium sand,

- a 4-inch layer of 50:50 peat-sand mixture, and
- an 18 inch layer of peat.

Water is collected and discharged from the perforated pipe directly to the surface water or groundwater system, and can be tied into the overall stormwater management/conveyance system.

Wet Ponds/Sand Filter Combination

Klein (1990) recommends a wet pond/sand (or peat) filter combination when infiltration is inappropriate or not possible. Wet pond water would travel through a filter system before discharge. Specific wet pond design criteria and requirements are listed in the King County Surface Water Design Manual. A wet pond/sand filter system has been reported to provide effective removal of metals (100%), nitrogen (80%) and phosphorus (80%) (Klein, 1990).

Treatment of Controlled Drainage from Greens with Granular Activated Charcoal (GAC)

The tiling of greens and tees is a common practice for capturing the soil water percolating downward in the soil column, and provides sufficient drainage from the golf course greens. The percolating water may be high in nitrates and/or pesticides from intensive management of the greens. Tiles may be used to capture and direct runoff away from the green to a swale, filter, wet pond, artificial wetland, or vault, for treatment before release. GAC systems have been considered as one additional treatment method. GAC systems applied to golf courses have not proven their effectiveness and are costly to install and maintain. At this time, their use is not recommended, and the following is provided for information only.

Effectiveness

Granular Activated Carbon is effective in the removal of synthetic organic compounds and other pollutants that contribute to taste, color and turbidity (Graese et al., 1987 and DeWater and DiGiano, 1990). GAC is an effective removal media because of carbon's superior absorptive properties (Nakhla et al., 1990). Activated carbon's extensive porous structure allows molecules to readily absorb to exposed surface areas (Pacific Northwest Weed Control Handbook, 1991). Maximum GAC adsorptive capacity is achieved when the contaminant capacity of the adsorptive material is in equilibrium with the solution surrounding the adsorbent element (Clark, Symons, Ireland, 1986). Application to golf course drainage is unproven.

Design Criteria

If employed, the GAC system would require proper design for the golf course areas the system would be serving. Specific GAC facility design criteria include the following: Empty Bed Contact Time (EBCT), liquid loading rate, tank operation, number of filters, flow rate, backwash rate an carbon bed expansion (Malear and Farabee). The amount of GAC require is based on the amount of residence or empty bed contact time required for proper treatment of the green-infiltrated water. Granular activated carbo parameters include the following: sieve size, mean particle diametei, effective size, uniformity coefficient, iodine number, hardness number, total surface area, density and pore volume (Melear and Farabee). The design o the GAC treatment system and all criteria would be specified in the specific Golf Course Management Plan. The system design, capacity and maintenance would address treatment of relevant chemicals proposed fo use in the Integrated Pest Management Plan.

The U.S. EPA (1989) recommends GAC as the best available technolog (BAT) for treating many organic and synthetic organic chemical spills, several of which are used for golf course management.

Monitoring

If a GAC system is employed, monitoring for effectiveness of the filte system should take place. Periodic monitoring would include checking the system flow rate and sampling for target chemicals. The monitoring should predict when a "breakthrough" in the GAC system occurs, triggering filte or GAC replacement.

Regulated Stormwater Control System

A regulated stormwater control system (developed by Ed McCarthy, Ph.D., P.E. of GeoDimensions, Kirkland, Washington) uses an adjustable flow restricto mechanism that physically controls stormwater flow from detention facilities. The system includes an adjustable flow restrictor mechanism, a sensor, a microcontroller, microprocessor, algorithms and an actuator. The sensor monitors environmental parameters and sends signals to the microcontroller. The system provides a constant discharge rate from the detention reservoir as the hydraulic head on the flow restrictor decreases, thereby minimizing required facility storage volume and making better use of available storage volume. The system may allow an increase in the average detention time of first-flush and low volume stormwater, allowing for an increase in quiescent settling conditions. The system provides an improved detention method to decrease the potential for overflow from the stormwater detention reservoir, thereby minimizing the occurrence of high discharge rates. This system has not yet been approved for use in King County.

Underdrain Leachate Collection System

An underdrain system can be used in conjunction with a surface water quality treatment facility, a GAC, sand or sand-peat filter system (Klein 1990), or a smaller water quality treatment system, in the following circumstances:

- under greens and possibly tees,
- under fairways, greens and tees sited on course textured soils, or that do not provide an adequate depth to the high ground water table elevation or to bedrock.

9.2 Impact Analysis Using Simulation Models

Criteria for Use

A number of computer simulation models that describe flow and transport in aquifers are applicable to estimating golf course chemical impacts. Many are particularly well suited to modeling nitrate and phosphate. Models are only as good as the input data, and in some situations, such as fractured bedrock, aquifer flow can be very difficult (if not impossible) to simulate. In addition, supplying models with data inputs can be very expensive (tens of thousands to over 100 thousand dollars). Consequently, consideration of whether a model is necessary, or whether available literature would suffice, is critical first step.

It is recommended that any golf course siting that cannot comply with the flow chart provisions in Figure 7-2, and that may use pesticides extensively or frequently, be a candidate for model simulation if existing literature is insufficient to allow prediction of impact potential. It is likely that an impact will occur under these situations unless other mitigation (such as linings) are implemented to preclude groundwater impacts. (Modeling would not normally be required for courses practicing only spot applications of chemicals, even if those chemicals are judged highly mobile or persistent, because of their limited use.)

Site Specific Parameters in Model Selection

The choice of a model to simulate nitrate and phosphate transport at a golf course location is influenced by physical, hydrological and chemical characteristics of a specific site. In selecting a model, the following factors should be considered:

1) the soil type, texture and mineralogy,
2) the slope of the land surface at the site,
3) presence, frequency and aperture size of fractures,
4) the water table configuration and seasonal variability,
5) proximity of the site to streams, lakes and wetlands,
6) fertilizer and chemical management types and frequencies and
7) site-specific environmental concerns.

Process Considerations in Model Selection

The relative importance of hydrological processes considered in the model is dependent upon whether nitrate or phosphate is being modeled, as well as the site-specific characteristics identified above. The following factors should t considered in choosing appropriate models:

1) method of analytical solution (direct, iterative, ability to handle non-linearity),
2) input data requirement (size and availability),
3) level of refinement and computer time required for solution,
4) level of expertise required to run the model, and
5) hardware and software requirements.

Categories of models acceptable to golf course managers are listed in Appendix D.

Model Concerns

Pesticide movement in soils is well summarized in Balogh and Walker (1992). Limitations in convective transport models are thought to arise from tl preferential movement of water through soil macropores, enabling pesticides t bypass the soil matrix that convective models assume is attenuating the leaching process. Thus, in some cases, equilibrium adsorption and dispersion/convectiv transport theory may underestimate transport. In addition, binding of pesticides b water-soluble organics such as fulvic and humic acids has been linked to subsurface movement of pesticides not normally associated with leachin Alternatively, thatch in turf has been shown to be an efficient trap to downwar movement of insecticides, which is underestimated by models. Only a growin body of site-specific data will allow greater understanding of the mass balance, fa and persistence of pesticides.

9.3 Pesticide Mobility and Persistence

This section describes evaluation criteria for identifying recommended chemica for use in golf course management, methods for evaluating these characteristi based on mobility and persistence rankings, and an assessment of existin chemicals in relation to these characteristics.

Pesticide Selection Cautions

It is important to note that while all the products listed in tables 9.4 and 9.5 are approved for use in Washington State, their safety to humans cannot be ful guaranteed by their inclusion in this manual. A site specific assessment must st be conducted and the following review is only included to highlight the types of risk that may be associated with pesticide use. It should not be assumed that Ki County has adopted a specific stance regarding any of the products listed towards the use of pesticides as a whole, other than to the extent indicated in th Best Management Practices contained in the rest of this manual.

The United States Environmental Protection Agency (EPA) derives it's authority over pesticides from the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). A controversial report recently issued by Robert Abrams, Attorney General of New York State notes (regarding the pesticide approval process under FIFRA) that "when the EPA permits a pesticide to be sold in the United States, the Agency does not decide that the product poses no environmental or health threats." The report goes on to say that FIFRA "requires the EPA only to decide that the pesticide poses no unreasonable risk to public health or the environment, based on its [perceived] economic, social and environmental costs and benefits. Before the EPA may register a pesticide and allow it on the market, the agency must first determine the risks are worth the benefits." Abrams goes on to suggest that "as more and more is learned about the extent of these risks--including the groundwater threat--this balancing act may tilt in the opposite direction, against the use of certain pesticides."

The EPA is currently reviewing the risk created by pesticide use. As of July 1991, only one of the 34 pesticides most commonly used on turf and lawncare had completed the required review (Abrams, 1991). "In the meantime thousands of pesticides still under review are freely marketed--unless the EPA decides to restrict or eliminate their use." As a consequence, in regard to pesticide use, "...Consumers do not know all the questions associated with pesticide use. Most importantly, no one has all the answers -- not the manufacturers, not the EPA..." (Abrams, 1991). This statement is reinforced to some degree by the fact that (as of July 1991) the EPA had only reviewed approximately one third of the studies submitted on the leaching characteristics of 16 pesticides known to contaminate groundwater (Abrams, 1991).

Abrams' comments need to be considered in context. The New York State report was written to consider the impact of pesticides used in golf course management on Long Island, where pesticides pose special risks due to the reliance on groundwater for drinking water and to the poor protection of the aquifers provided by the local soils (Abrams, 1991). Abrams also clearly states that there is no reason to conclude that any water now supplied to Long Island exceeds safe drinking water guidelines for any pesticide.

The report does, however, seek to show the potential for damage to the groundwater resource due to long term use of pesticides in sensitive areas. The report concludes with a series of generic recommendations that aim to (a) reduce the overall amount of pesticides used, (b) reduce the hazards associated with pesticides and (c) seek to ensure the users and the public are fully appraised of any risks to which they may be exposed.

If implemented, the proposals contained in the report could significantly impact current turf management practice: they reinforce the importance of stringently following the pesticide selection process and IPM guidelines contained in t manual. The Abrams (1991) recommendations are listed below.

- The use of pesticides for aesthetic purposes (including golf courses) containi known or probable carcinogens should be prohibited by the EPA or by federal law.
- All labels should state in simple language that any pesticide use "may pose potential health and environmental risks."
- Pesticide labels should state clearly that registration is not a guarantee that pesticide use is free of risk.
- Congress should amend the federal pesticide law to enable private individuals to sue and recover legal costs to halt false and deceptive pesticide safe claims.

The Abrams (1991) report also adopts the following recommendations (made the U.S General Accounting Office (GAO) 1991 study on pesticides ... groundwater):

- EPA should require groundwater advisories on the labels of pesticides known to cause widespread groundwater contamination.
- EPA should ban the use of pesticides known to leach into groundwater wherever groundwater is particularly vulnerable to pesticide contamination.

The GAO report identified six pesticides capable of entering groundwater after normal application following label directions. These were chlorothalonil, dactha dicamba, 2,4-D, prometon and trifluralin. (Prometon and trifluralin are not used the Pacific Northwest; however, the six products listed above constituted 22.6% of the pesticides used by the 52 golf courses in the Long Island survey. By 1988, tw of these products - chlorothalonil and dacthal (respectively the first and seco most heavily used products in the Long Island area) had been detected in Long Island groundwater at the highest levels anywhere in the country. This occurr despite these products being classified as having a "small" leaching potential (on scale of large, medium, small and very small), by the SCS/ARS/CES Pesticide Properties Database produced by the U.S.D.A Soil Conservation Service in 1991

(In 1989, after dacthal had been applied on Long Island and subsequentl discovered in groundwater at levels 20 times above the state safe drinking wat standards, the New York State Attorney General's Office sued the manufacturer to establish the extent of the contamination and to develop a water treatmen program. The case was still in litigation at the time the Abrams report w printed).

Chlorothalonil and trifluralin (and fosetyl-AL) have also been classified by EPA as possible or probable human carcinogens. In addition another three products listed in Table 9.5 (trichlorofon, mancozeb, maneb) naturally break down in the environment into various substances which are possible human carcinogens.

Some formulations of Dacthal also have been documented by the EPA as being contaminated with traces of dioxin (2,3,7,8 TCDD) - a suspected human carcinogen that induces reduced vigor and increased mortality in rainbow trout at levels as low as 38 parts per quadrillion. (Mehrle et al., 1987)

Other dioxin relatives (2,7 dichloro dibenzo-p-dioxin or DCDD) have been found by EPA in US produced formulations of 2,4-D (USDA, 1988). Although this contaminant occurred in only 3 of 30 samples and is a million-fold less toxic than its more notorious relative (2,3,7,8 TCDD), the presence of this chemical indicates the potential risks presented by the possible presence of materials other than the active ingredient. 2,4-D also may contain "minute traces" of 2,4 Dichlorophenol (2,4-DCP) - a product whose effects on human health "has not been well studied", although it has been found to be a "weak tumor promoter" (USDA, 1988). These risks, however small, occur in addition to those presented by the actual chemical 2,4-D, for which the World Health Organization (1984) concluded that, "the carcinogenic potential of 2,4-D and its derivatives such as the amine salts and esters has not been adequately tested. The reports on animal bioassays carried out so far are either too brief for proper evaluation or have been the subject of scientific controversy." (USDA, 1988).

The USDA, in the record of decision for the study cited above, concludes by stating "with respect to 2,4-D, studies about its cancer causing potential have conflicting results - some show a positive correlation with cancer, others do not. Although the studies completed to date do not support a conclusion that 2,4-D causes cancer, the question remains unresolved." In reaching the decision to use 2,4-D as a last resort, the report also considered "the demonstrated potential for adverse neurotoxic, reproductive and developmental effects" attributed to the chemical (USDA, 1988).

The debate regarding 2,4-D has continued and in October, 1992 the EPA established an agreement with the task force representing the registrants of 2,4-D that required the introduction of label changes "in order to ensure reduced exposure to the product". This also required the task force to carry out consumer education programs highlighting the reasons for the exposure reduction measures and requiring the provision of a telephone hotline service. These measures were taken as an alternative to the EPA beginning procedures leading to the suspension of their products for failure to meet deadlines for submitting certain health and safety data to the Agency (EPA Press Release, 1992).

These findings reinforce the need for an accurate and realistic assessment (pesticide health risks. In addition, the USDA and New York State reports bo(make clear that the active ingredients are not necessarily the only toxic ingredients in a pesticide, and are therefore often not the only factor to be considered whe evaluating risks. So called "inert" components present in commercial products a considered "confidential business information" by EPA.

In an unusual step, the USDA investigated the inert components of the products used in applying the 16 pesticides proposed for use. They concluded that th analyses conducted for the main constituents adequately summarized the risk (the product - except for the petroleum distillate bases of 2,4 D and Triclopyr "which had a high priority for testing". A study (cited in the USDA report), b Bingham et al., 1979, has shown a positive correlation between polycycli aromatic hydrocarbons and the formation of cancer in humans, (although this potential is 6000 times less than that of 2,4 D itself). The same study showe Atrazine, Diuron and Simazine to contain formaldehyde - a known strong irritar and a carcinogen (USDA, 1988).

EPA does not require chronic testing of the full pesticide formulation (activ ingredient and "inert" carrier plus possible contaminants). As a consequence, none of the products used by the USDA underwent chronic toxicity testing. (Thi would include tests for carcinogenicity and for any systemic reproductive, developmental, or mutagenic effects). The report concluded that "the possibility that the formulated product is more toxic than the active ingredient cannot b discounted entirely. Neither can it be assumed to be true." This again reinforces the need for operator care.

The same report also tabulated the risks from an accidental prolonged "worst case scenario" exposure to each of the 16 pesticides proposed for use. The study assumed that workers spilled one pint of chemical on themselves when not wearin protective clothing, and that they did not wash the chemical off. The report concluded "this [would] represent a clear risk of severe toxic effects. There i some possibility that the damage done by such a large acute dose could result in long term damage to vital organs."

Of the 16 pesticides in the Forest Service study amitrole, asulam, atrazine, bromacil and 2,4-D and 2,4-DP registered positive oncogenic responses, while picloram had an unproven but suspected oncogenic record. Actu epidemiological studies have produced uncertain results, with studies by the National Cancer Institute showing that farmers have an overall lower cancer death rate than the general population. They also, however, have a higher risk (developing lymphatic and blood related cancer, including leukemia, and cancer o the prostate, skin and stomach (USDA, 1988).

No single agricultural factor has been consistently associated with an increased rate of specific cancer but neither can the risk be ignored. While some studies have shown no correlation between cancer and pesticide use, other studies have shown a higher number of deaths in licensed pesticide applicators in Florida due to leukemia and cancers of the brain and lung . The risk of lung cancer rose with the number of years licensed (USDA, 1988).

It is important to remember the findings quoted in this section represent an extremely limited review of the available literature and are limited to a discussion of human health risks rather than those created for other living organisms. The findings quoted are only included in this report to exemplify and emphasize that the use of pesticides may involve risk to the operator and the environment. King County is NOT adopting a negative stance to pesticide use, but IS advocating that all possible risks are clearly identified and understood. This means that all relevant factors are fully considered and the potential for using alternative methods of pest and disease control other than pesticides are carefully evaluated and defined. King County is committed to both a risk assessment to evaluate potential adverse effects and an alternatives assessment to assure that a full range of viable options are considered. The County also wishes to ensure good practices that maximize public and operator safety and environmental health. A full review of information regarding potential health impacts of pesticides is beyond the purview of the manual, but detailed information can be obtained from the EPA. Those concerned with health risks can also obtain advice and information from the U.S. EPA and the Washington Toxics Coalition, 4516 University Way N.E, Seattle, WA 98105 (phone 632 -1545).

Pesticide Evaluation Criteria

Several criteria have been advanced to evaluate the environmental hazard potential of chemicals used to control a variety of pest organisms (e.g. annual herbs and grasses, fungi and insects). These criteria divide into two main areas - the chemical and physical nature of the pesticide and the biological impact of the pesticide on specific organisms. Target specificity, target efficacy, cost, and application amounts and methods are additional criteria the course superintendent will use in final chemical selection.

Relevant chemical and physical characteristics of pesticides include water solubility, volatilization rates, adsorption and retention characteristics, and decomposition and persistence rates. Collectively, these characteristics describe the residence time of a chemical in the environment and the potential for movement through the environment from the point of application.

The biological impact characteristics of a chemical can be defined by the results of acute and chronic toxicity tests conducted on organisms of interest (e.g. mammals, birds, fish, and plants). Acute toxicity tests use the death of the test organism as the endpoint (typically 48-96 hour test periods). Acute toxicity test results a reported as the LC50 for aquatic organisms (the median lethal concentration of th compound in water) or as the LD50 for terrestrial organisms (the median lethal dose per kilogram of organism weight). In contrast, chronic toxicity tests use th reduction in growth (measured by weight) or reproduction as the test endpoint (test periods typically lasting 7-20 days). Chronic bioassay results are frequentl reported as the NOEC (No Observed Effect Concentration).

These criteria have found application in two major golf course initiatives - the *New York State Adirondack Park Agency Study* (Rottier et al. 1988) and the *Cape Co Study* (Cohen 1990; Cohen et al. 1990; Horsley and Moser 1990). Both of these large-scale research efforts used various combinations of pesticide persistence movement (both surface and subsurface) and toxicity to create a usage ranking fo golf course pesticides. Both involved pre-existing golf courses, where the water table, surface and subsurface flow characteristics were already known. The Cap Cod and New York approach has been modified in this manual to create a mor generic model that could be used as one part of the chemical selection process for golf courses in King County.

Chemical Mobility/Persistence Initial Screening Model

The basic approach of this initial screening pesticide model is centered on an assessment of resource exposure. If the resources to be protected are never exposed to the pesticide, then the toxicity of the pesticide is relatively unimportant It should be noted that pesticides should never be applied outside of the course boundaries, or in streams, wetlands, and lakes. In this model, pesticide mobility (represented quantitatively in the model as the organic carbon partition coefficient Koc) and persistence (half-life, t0.5) are used as first-order screens to estimate the degree of movement and longevity of the chemical in the environment (see Table 9-1 for specific categories). Persistence ratings were taken from Balogh et al 1990; Balogh and Walker 1992; Carselet al. 1984; Nash 1988; Rao and Davidson, 1980; Wauchope et al. 1991. Partition coefficient numbers were taken from Balogh and Walker 1992; Carsel et al. 1984; Howard 1991; Jury et al. 1987 Karickhoff 1981; Kenaga 1980; Kenaga and Goring 1980; McCall et al. 1981; McCall et al. 1983; Rao and Davidson 1980; Wauchope et al. 1991; EPA 1988.

Chemicals with limited water solubility and/or short half lives will rarely pose a hazard to the environment when applied appropriately. Golf course topograph and water movement patterns will be an additional influence on the movement o pesticides from the point of application towards adjacent natural resources. In contrast, chemicals with high mobility and/or long persistence times may reach surface or ground water resources. Consequently, the use of these chemicals should be strongly influenced by the intended application amount and methods application location, season, toxicity ratings, presence of aquifers, and organism potentially at risk in the environment (see Table 9-2). Toxicity ratings in this model were taken from Murphy 1990, 1992; EPA 1985; USDA 1969; EPA 1988. No toxicity ratings are presented for human operators because it is assumed that all pesticides are applied with appropriate OSHA safety precautions.

Table 9-1. Chemical Mobility and Persistence Scales

Mobility Rating	Koc*
0	>5,000
1	1,000 - 5,000
2	<1,000
Persistence Rating**	**Half Life, t0.5 (days)**
1	1 - 4
2	5 - 9
3	10 - 49
4	50 - 99
5	>100

* Organic carbon partition coefficient.
**Modified from Balogh and Walker, 1992.

Source: Beak, 1992.

In constructing the model, the chemical mobility (as measured by organic carbon partition coefficient) was assumed to have a greater influence on estimated chemical exposure than persistence. Chemicals with high Koc's will bind strongly to soil components and move very little regardless of their persistence in the environment. As the organic partition coefficient decreases, persistence plays an increasingly important role in determining the level of pesticide exposure to the natural resource.

The choice of the organic carbon partition coefficient to represent pesticide mobility is substantiated by the high organic matter content of the turfgrass thatch layer (Balogh and Walker 1992). Several studies have demonstrated that the adsorption properties of most inorganic and organic pesticides are highly correlated with soil organic matter content (Balogh and Walker 1991, p. 266). Thus, movement of a pesticide will be indirectly related to the organic carbon partition coefficient (Koc). Pesticides with high Koc values (greater than 5,000) will be so strongly adsorbed that they functionally will never move (such as

Toxicity* Rating	LC50 mg/L	Class	LD50 mg/kg	Class
1	> 100	Practically Nontoxic	>4999	Almost Non–Toxic
2	10–99.99	Slightly Toxic	500–4999	Slightly Toxic
3	1–9.99	Moderately Toxic	50–499	Moderately Toxic
4	0.1–0.99	Highly Toxic	5–49	Very Toxic
5	< 0.1	Very Highly Toxic	<5	Extremely Toxic

*Modified from Balogh and Walker, 1992, p. 447.

BIOLOGICAL DEFINITIONS	
Mammal:	Warm blooded, usually hairy vertebrates who feed their offspring milk. Examples – Rats, Humans.
Fish:	Cold blooded invertebrates living in water and having permanent gills for breathing, fins and usually scales. Examples – Steelhead, Salmon.
Amphibia:	Vertebrates that usually begin life in the water as tadpoles with gills and later develop lungs. Examples – Frogs, toads and salamanders
Crustacea:	Arthropods with a hard outer shell that typically live in water. Examples – Shrimps, crabs and barnacles.
Mollusca:	Invertebrates with a soft body, partially or wholly enclosed by a hard shell. Examples – Snails, oysters and mussels.
Bird:	Warm blooded vertebrates which lay eggs with feathers and wings. Examples – Spotted owls, marbled murrelets and bald eagles.
Insecta:	Small, segmented invertebrates with a hard outer body. Examples – beetles, bees and and mosquitoes.
Annelida:	Small, segmented worms. Examples – earthworms and leeches.

Table 9–2. Toxicity and biological definitions found in Table 9–4.

glyphosate, amine salt with a Koc of 24,000). In contrast, dicamba salt has a Koc of 2.2, and will move through the environment, for all practical purposes, at the same rate as water. The specific rating categories chosen (see Table 9-1) are broadly conservative, with the highest mobility rating (2) including compounds with extremely high and moderate mobilities. Compounds with the intermediate mobility rating (1) should have relatively limited movement, while those rated (0) are, to all intents and purposes, non-mobile. Field data, when available for the specific soil types and climate of a proposed course, should always be weighted more heavily than these broad rankings based on Koc.

Koc and half-life data were combined to produce a mobility/persistence (M/P) rating (see Tables 9-1 through 9-3). Chemicals that are very short lived or practically immobile were assigned a M/P rating of A while chemicals that are highly persistent and highly mobile were assigned a M/P rating of D (see Table 9-3). Based on the M/P rating, toxicity classes were then considered in recommending the use of a pesticide. Chemicals with M/P ratings of A can be recommended for broad use even with a relatively high toxicity class rating. Chemicals with M/P ratings of D would be recommended for broad use only when the toxicity class ratings are low (see Table 9-4) or application amounts are low.

Example of Pesticide Screening Selection

The workings of the model can be examined by comparing three fungicides: etridiozole, benomyl and chlorothalonil. Etridiozole is only slightly toxic to mammals and amphibians. It has immediate mobility with an intermediate life span and therefore receives an M/P rating of low risk (see Tables 9-4 and 9-5). Benomyl, in contrast, has an M/P rating of D (intermediate mobility and highly persistent) and is highly toxic to fish. Its widespread use would be strongly discouraged except in courses were design features create very high transport times to resources of concern. An intermediate example would be chlorothalonil. This chemical received a M/P rating of caution in the screening model. Chlorothalonil has relatively intermediate toxicity to most organisms tested. However, field data demonstrate that it has contaminated groundwater (Abrams, 1991), and therefore, chlorothalonil should be avoided unless usage is extremely minimal or limited, or the conclusions of the Abrams (1991) report are not substantiated by site investigation. It is emphasized that field data and compound-specific test results should always be sought subsequent to initial screening.

Interfacing M/P Model with Transport Times

The recommendations of the chemical mobility/persistence model should be linked with the specific transport times for a particular golf course and the likely or intended application regimes, to create a site-specific pesticide usage plan. Thus, chemicals with low M/P ratings (C or D) could still be used in courses where the calculated transport times will limit the movement of chemicals from point of

CHEMICAL MOBILITY AND PERSISTENCE

Persistence \ Mobility	0	1	2
1	*A*	*A*	*B*
2	*A*	*B*	*C*
3	*A*	*B*	*C*
4	*A*	*C*	*D*
5	*A*	*D*	*D*

Mobility Categories

0 = Practically Immobile
1 = Low mobility
2 = High Mobility

Persistence Categories

1 = Very Short Lived
2 = Short Lived
3 = Moderately Short Lived
4 = Moderately Persistent
5 = Highly Persistent

Combined Persistence and Mobility Categories

M/P Rating *A* = Zero Persistence or Zero Mobility
M/P Rating *B* = Low Persistence or Low Mobility
M/P Rating *C* = High Persistence or High Mobility
M/P Rating *D* = High Persistence and High Mobility

Table 9–3: Combined chemical mobility and persistence ratings system.

Table 9–4. Mobility, persistence and toxicity data for potential turfgrass pesticides. Pesticides marked with a '*' are commonly used in Washington, ones marked with a '–' are seldom used.

Type Designations:
f = fungicide, h = herbicide, i = insecticide

Pesticide	Type	Mobility	Persistence	M/P Rating	TOXICITY CLASSES: No Data	Mammal	Fish	Amphibia	Crustacea	Mollusca	Bird	Insecta	Annelida
Benomyl *	f	2	5	*D*			4						
Chloroneb	f	1	5	*C*	x								
Chlorothalonil *	f	1	3	*B*		3	5	4	3	3		3	
Etridiozole	f	1	3	*B*		2		2					
Fenarimol *	f	2	5	*C*	x								
Fosetyl Al *	f	2	1	*B*	x								
Iprodione *	f	1	3	*B*	x								
Mancozeb *	f	1	3	*B*		5	4		3				
Maneb	f	1	4	*C*		1	4	2	3	1			
Metalaxyl *	f	2	5	*D*	x								
PCNB *	f	0	5	*A*		2	3						
Propamocarb HCl	f	0	3	*A*	x								
Propicanozole *	f	2	5	*D*	x								
Thiophanate–methyl *	f	1	2	*B*		2	3		2				
Thiram	f	2	3	*C*			5	5	3			4	4
Triadimefon *	f	2	3	*C*	x								
2,4–D butoxyethyl ester *	h	1	3	*B*		5	3		3	4	3	3	
Atrazine	h	2	1	*B*			3	4	1			4	3
Benefin –	h	1	1	*A*		2	4	2	3				
Bensulide –	h	1	3	*B*		3	4		3				
DCPA –	h	0	4	*A*		1	2		2				1
Dicamba *	h	2	2	*C*			2	1	2				
DSMA	h	1	n/a	n/a		2	2	1	2				
Endothall *	h	2	2	*C*			3				3		
Ethofumasate *	h	2	3	*C*	x								
Fenoxaprop	h	n/a	n/a	n/a		2	2		3				
Glyphosate acid	h	1	3	*B*			3		2			2	
Glyphosate amine salt/Roundup *	h	1	3	*B*		3	2		2			2	
MCPA, ester *	h	1	3	*B*			2		2		3	1	
MCPA, salt *	h	2	3	*C*			2		2		2	1	
MCPP (Mecoprop) *	h	2	3	*C*	x								
MSMA, sodium salt	h	0	1	*A*			2						
Oxadiozon –	h	0	4	*A*			3	3					
Pendimethalin –	h	0	3	*A*	x								
Siduron	h	1	4	*C*	x								

Table 9–4. Continued

Type Designations:
f = fungicide, h = herbicide, i = insecticide

Pesticide	Type	Mobility	Persistence	M/P Rating	TOXICITY CLASSES: No Data	Mammal	Fish	Amphibia	Crustacea	Mollusca	Bird	Insect
Simazine	h	2	4	*D*		5	3	1	2		3	3
Triclopyr, triethylamine salt *	h	2	4	*D*		5					4	
Triclopyr. butoxyethyl ester *	h	1	4	*C*		5					3	
Trifluralin	h	0	5	*A*			4	3	4	3		3
Bendiocarb *	i	2	2	*C*		4			3			[illegible]
Carbaryl *	i	2	2	*C*		3	4	2	4	2		
Chlorpyrifos *	i	0	3	*A*			5		5	4		5
Ethoprop	i	2	4	*D*							5	
Fenamiphos	i	2	3	*C*		4	4					
Isazofos	i	2	3	*C*	x							
Isofenphos *	i	2	5	*D*	x							
Trichlorfon *	i	2	2	*C*		4						

Mobility	Persistence	Toxicity Classes
0 = Practically Immobile	1 = Very Short Lived	1 = practically nontoxic
2 = Highly Mobile	5 = Highly Persistent	5 = very highly toxic

Toxicity Ratings are modified from Balogh and Walker, 1992, p. 447.

Table 9–5. General risk assessments based solely on the first screening chemical mobility/persistence model. Application amounts and methods and product specificity and efficacy must also be weighed in the selection process. The '*' and '–' are the same as in Table 9–4.

Pesticide	Pesticide Type	First Screening Risk Assessment
Propicanozole *	Fungicide	Risk Very High
Propamocarb HCl	Fungicide	Risk Low
Iprodione *	Fungicide	Risk Low with Precautions
Fosetyl Al *	Fungicide	Risk Low with Precautions
Metalaxyl *	Fungicide	Risk Very High
Fenarimol *	Fungicide	Risk Very High
Etridiozole	Fungicide	Risk Low
PCNB *	Fungicide	Risk Very Low
Maneb (c)	Fungicide	Caution
Mancozeb * (c)	Fungicide	Caution
Chloroneb	Fungicide	Risk High
Thiram	Fungicide	Risk Very High
Thiophanate–methyl *	Fungicide	Risk Low
Triadimefon *	Fungicide	Risk Very High
Chlorothalonil * (a)	Fungicide	Caution
Benomyl *	Fungicide	Risk Very High
MCPA, salt *	Herbicide	Risk Low with Precautions
Triclopyr. butoxyethyl ester *	Herbicide	Risk High
MCPA, ester *	Herbicide	Risk Low
Triclopyr, triethylamine salt *	Herbicide	Risk Very High
Simazine	Herbicide	Risk Very High
MCPP (Mecoprop) *	Herbicide	Risk High
Siduron	Herbicide	Risk High
Oxadiozon –	Herbicide	Risk Very Low
Pendimethalin –	Herbicide	Risk Very Low
Glyphosate amine salt/Roundup *	Herbicide	Risk Low
MSMA, sodium salt	Herbicide	Risk Very Low
2,4–D butoxyethyl ester * (b) (d)	Herbicide	Caution
DSMA	Herbicide	Risk Low with Precautions
Dicamba * (b)	Herbicide	Caution
Atrazine	Herbicide	Risk Low
Benefin –	Herbicide	Risk Very Low
Bensulide –	Herbicide	Risk Low
DCPA –	Herbicide	Risk Very Low
Trifluralin – (a) (b)	Herbicide	Caution
Endothall *	Herbicide	Risk Low with Precautions
Fenoxaprop	Herbicide	Risk High
Ethofumasate *	Herbicide	Risk High
Glyphosate acid	Herbicide	Risk Low

Table 9–5. Continued

Bendiocarb *	Insecticide	Risk High
Trichlorfon * (a)	Insecticide	Caution
Fenamiphos	Insecticide	Risk High
Isazofos	Insecticide	Risk Very High
Carbaryl *	Insecticide	Risk High
Chlorpyrifos *	Insecticide	Risk Low
Ethoprop	Insecticide	Risk Very High
Isofenphos *	Insecticide	Risk Very High

(a) Listed by U.S. EPA as a possible carcinogen.
(b) May be capable of entering ground water (after following label user guidelines).
(c) May degrade into carcinogenic compounds.
(d) May contain mixture contaminants.

application to adjacent resources. They could also be used when dry seasonal application would preclude transport to these adjacent resources, or when the applied amounts are very low. Additionally, chemicals with high M/P ratings (A or B) should be used with caution in course environments where transport times are high.

9.4 Additional Criteria for Protection of Special Areas

Relating pesticide or fertilizer use in a site-specific manner to protection of surrounding resources requires consideration of a number of factors (Table 9-6). Chief among those is recognition of the seasonality of pesticide or fertilizer application. Pesticide applications for Northwest golf courses usually occur between April and August or April and October on an as-needed basis. Because water movement is the mechanism (transport vector) through which off-course exposure of aquatic flora and fauna are exposed to golf course management chemicals, the difference between wet season and dry season use has a direct bearing on exposure potential and selection of chemicals.

As discussed in Chapter 7, the rate of transport in the interflow (shallow subsurface) water is not completely understood. Two theories with very different linear velocity results have been developed to explain empirical data. Distinguishing between these two theories should be a research priority. The results of both theories are shown in Table 9-6

Based on season, slope and the choice of interflow conductivity model, M/P ratings for pesticide selection (as defined in Section 9.1) are provided for a fairway immediately adjacent to a 100-foot wetland buffer in Table 9-4. There are no well-established data for quantitatively relating pesticide transport rates to water interflow transport rates based on organic carbon partition coefficients. An example of pesticides rated as having 'high' (dicamba), 'moderate' (atrazine) or 'low' (chloropyrifos) transport potential is shown below. Some data for vertical movement are provided below for these classes (Jury et al. 1987). Note that as a conservative measure of horizontal transport, the M/P model in Section 9.1 assigns a mobility rating of 2 (high to moderate mobility classification) to both atrazine (moderate) and dicamba (high), and a mobility rating of 1 (moderate to very low mobility classification) to chloropyrifos.

Pesticide	'High Leaching Potential Condition' Time to Reach 3 Meters Depth in Soil (years)	Organic Carbon Partition Coefficient
Dicamba	0.6	2.2
Atrazine	4.2	160
Chloropyrifos	137	6,000

Table 9–6. Relating M/P pesticide ratings to slopes and buffer widths.

CRITICAL FACTORS IN ESTABLISHING ENVIRONMENTAL TRANSPORT

SEASONALITY
Length of time between storms
Season(s) of pesticide application

SLOPES
Average slope of fairways, surroundings & buffers

DISTANCE
Distance between course and downslope resource

M/P RATING and TOXICITY
Results of pesticide selection approach from Tables 9–1 through 9–5

APPLICATION AMOUNT
Consider the intended or likely amount of pesticid be used.

INTERFLOW CONDUCTIVITY MODEL
Macro–pore versus pre–event theories on interflow average linear velocities give very differe interflow velocity rates through soil. Resolution as to which is the better model will require f research. The macro–pore theory (280 ft/day conductivity) is more conservative than the pre–event theory (28.0 ft/day conductivity). See Section 7 for detailed discussion.

APPLICATION EXAMPLES

Fall/winter/spring conditions with storms >0.1 inches/day every 1.7 to 2.2 days on av

Fairway to edge of 100–foot wetland buffer, with 5 percent and 10 percent slopes.

Slope	Average Interflow Water Transport Distance per Day		For High to Moderate Toxicities, Recommended M/P Ranking	
	Conductivity		Conductivity	
	280 ft/day	28 ft/day	280 ft/day	28 ft/day
10 %	140 feet	20 feet	A Rank Only	A or B Rank
5%	60 feet	10 feet	A or B Rank	A, B or C Rank

Summertime conditions with storms >0.1 inches/day every 4.5 days on average.[1]

Fairway to edge of 100–foot wetland buffer, with 5 percent and 10 percent slopes.

Slope	Average Interflow Water Transport Distance per Day		For High to Moderate Toxicities, Recommended M/P Ranking	
	Conductivity		Conductivity	
	280 ft/day	28 ft/day	280 ft/day	28 ft/day
10 %	56 feet	8 feet	A Rank Only	A, B or C Rank*
5%	24 feet	4 feet	A or B Rank	A, B or C Rank*

** D– ranked pesticides are not recommended in quantity because of half–lives greater than or longer than the summer dry season, and because of high mobilities. When the wet seasor commences, this category of pesticides would still have residual amounts available for transp*

[1] Averaged seasonal interval between storms at SeaTac Airport, provided by Northwest Weather Interflow will continue at designated rates for approximately three days after a storm. Therefo interflow rates were assumed constant during the fall through spring, but intermittant during the s

Table 9-7. One scenario for a potential maintenance schedule for an 18-hole golf course (from the U.S. Professional Golf Association for a Pacific Northwest course).

Characteristic	Application Season	Approximate Quantity	Approx. Total Use per Year
Irrigation:			
Irrigation Season	April through October		
Irrigation Peak	June through September		
Fertilization:			
Greens & Tees (3 acres of each)	As Needed	N: 6 lbs / 1000 ft.^{2} /year slow release P: 2 lbs / 1000 ft.^{2} /year K: 4-5 lbs / 1000 ft.^{2} /year	
Fairways (72 acres)	As Needed	N: 3 lbs / 1000 ft.^{2} /year slow release P: 0.5 lbs / 1000 ft.^{2} /year K: 1 lbs / 1000 ft.^{2} /year	N: 12,883 lbs/year P: 1,851 lbs/year K: 4,857 lbs/year
Roughs (25 acres fertilized; 50 acres unfertilized)	As Needed	N: 1.5-2 lbs / 1000 ft.^{2} /year slow release P: 0.25 lbs / 1000 ft.^{2} /year K: .5 lbs / 1000 ft.^{2} /year	
Pesticides:			
Herbicides	Dry Season Applications 1-2 times /year (April through August as needed)	Bensulide; Greens/Fairways 2 times/year @ 0.17 lbs/1000 ft.^{2} Tees 2 times/year @ 0.6 lbs/1000 ft.^{2} 2,4-D+MCPP; Tees 1 time/year @ 0.03 lbs/1000 ft.^{2} Fairways 1 time/year @ 0.25 lbs/1000 ft.^{2} Roughs 1 time/year @ 0.02 lbs/1000 ft.^{2}	<u>Maximum Possible Use</u> Bensulide: 1,300 lbs/year 2,4-D+MCPP: 1,200 lbs/year
Insecticides	Dry Season Applications 2 times /year (April through August as needed)	Dursban 2E; Greens only 2 times/year @ .05 lbs/1000 ft.^{2} Trichlorfon 80 SP; Tees/Fairways 2 times/year @ .25 lbs/1000 ft.^{2}	Dursban: 12 lbs/year Trichlorfon 80 SP: 1,650 lbs/year
Fungicides	Dry Season Applications 4-6 times /year (April through October as needed) To Greens	Triadimefon; 1-2 times/year @ .12 lbs/1000 ft.^{2} Iprodione; 1-2 times/year @ .12 lbs/1000 ft.^{2} Fenarimol; 1-2 times/year @ .16 lbs/1000 ft.^{2}	

Using the analysis sequence provided in Table 9-6, which assumes as a ve conservative estimate that moderately mobile compounds will move laterally at to 10 percent the rate of interflow water, only A-ranked pesticides should be used in any quantity at the edges of 100-foot buffers. This recommendation is based transport potential only. Subsequent to transport and the amount of pesticide remaining at arrival, exposure and toxicity must be considered. *If the toxicity is low or the indirect targets of those pesticides are absent from the resource concern, their use will be not be problematic, and B-ranked or even C-ranked pesticides may be acceptable.*

(Note that as a conservative measure, this screening model combines both dicamba with high transport potential and atrazine with moderate transport potential into one mobility rating of "2". For all pesticides, specific transport potential data should be sought; particularly field data. Some compounds, such as trifluralin, have high Koc's and should be immobile, yet are indicated by the GAO (1991) as capable of entering groundwater.)

In many cases, transport via interflow will only occur from the fairways to natural or created swales, which may either bisect fairways or run parallel to their edge. Natural drainage swales would likely have 25- foot buffers, and distance from application sources of the pesticides to these channels would need to be considered carefully in chemical management. Tees or greens are the only application sites for many pesticides, and intervening fairways will act to retard pesticide transport. It appears that 100- foot distances between application sites and resources having percent slopes or less are adequate if chemical selection is sensitive to transport potential and the season of application, (particularly since in the absence of quantitative data the analysis is purposely conservative.) These 100-foot distances may include untreated fairway, roughs and any intervening open areas. Golf turf appears to particularly well suited to prevent transport of organic chemical (Section 9.1) and on-site monitoring programs now being established for new courses should provide valuable data for reevaluating recommended management chemicals based on distance from a receiving aquatic resource.

Best Management Practices

- Follow the chemical selection procedure outlined in Section 9.1 for broadly used pesticides.

- Determine the relationship between chemical M/P ratings, season of application or use, distance and slope between the pesticide application area and the aquatic resource of concern, and the intended application amounts.
- Following the procedure outlined in Table 9-6, calculate the fall/winter/spring average water interflow transport distance based on slope for pesticides to be applied during those seasons, or the summer average water interflow

transport distance based on slope for pesticides to be applied during the summer season (40% of the wet seasons's rate).

- Calculate pesticide transport as zero for mobility rankings of 0 (Table 9-1), 5 percent of the water transport rate for mobility rankings of 1, and 10 percent of the water transport rate for mobility rankings of 2.

- Calculate the number of days estimated for the pesticide to travel from the application area to the aquatic resource, and select a persistence ranking from Table 9-1 with a half-life approximately one/half of the calculated transport time (as discussed above).

- Based on the mobility and persistence determined acceptable (as discussed above), determine the M/P rating from Table 9-3.

- Select the appropriate pesticides from Table 9-4. If the M/P rating for a particular necessary pesticide is lower than that determined acceptable above, determine if low toxicity or spot application (i.e., very low application amount) alleviates concern, or if a lack of acceptable alternatives necessitates use. Detail those exceptions. Examine potential for upland wildlife or bird species impacts.

- Monitor to determine actual transport rates of applied chemicals and adjust the calculation of pesticide lateral transport accordingly.

- Post notices whenever pesticides are applied, as required by state law.

9.5 Water Quality Monitoring

Monitoring for pest populations to evaluate pest occurrences and establish action thresholds (Ball and Marsan, 1991) as part of IPM has been discussed in Chapter 8. Biological monitoring for wildlife and aquatic biota has been discussed in section 4.2. Because it is well documented that pesticide movement from golf courses can be difficult to predict, the results of pesticide usage as dictated by an IPM strategy should be measured for each course to complete the feedback information cycle to an effective IPM (see Figure 8-1).

To monitor for the accuracy of the PRZM model's predictions for pesticide transport on the Yarmouth Golf Course in Cape Cod Massachusetts, a groundwater monitoring program was developed to serve as an early warning protective device for the City of Yarmouth's drinking water aquifer (Horsley and Moser 1990; Cohen et al. 1990). Because of the proximity of the course to the aquifer and the sandy soils underlying the golf course, concern for aquifer quality impact was extreme. Six to ten wells were proposed at the downgradient boundary of the golf course and downgradient of the pesticide storage facility.

Lysimeters and tensiometers were placed upgradient of the wells to serve as earlie warning systems than the wells, and to enable better tailoring of the well samplin regime. The monitoring protocol included resampling for confirmation of pesticide presence, staged monitoring frequencies depending upon the results, restriction c pesticide use during resampling and testing, criteria for remedial action anu temporal criteria for resumption of base monitoring frequencies based on lack of detectable pesticides for two years following detection. Fertilizer-based nitroge was also monitored in the system with established criteria for increasing sampling criteria if total nitrogen exceeded 5 mg/l and restriction of fertilizer use. Remedia' action criteria were also established for nitrogen.

The Yarmouth Golf Course monitoring plan is effective because it employs al' basic monitoring principles. These are consolidated and expanded in the followin recommended procedures for establishing a golf course monitoring plan:

- Define the objectives of the monitoring program in writing. Establish the resource of concern, the transport route and vectors driving transport, and develop a hypothesized connection between pesticide or fertilizer use anc impact that the monitoring would need to indicate.

- Determine by model, literature review or simple calculation estimated transpon times for management chemicals to the resources of concern so that a reasonable monitoring frequency can be established.

- Use the site's surface and subsurface flow characteristics to establish early warning and definitive impact stations between the site of application or use and the resource being protected, and to avoid placement of stations where they will be ineffective (i.e. not downgradient or below an impervious layer). Be sure that the type of station matches the monitoring frequency and method (i.e., stream, wetland, pond, aquifer and interflow monitoring frequencies will all be different based on differential transport rates and differences in response to runoff events).

- Use staged monitoring. Establish criteria for either increasing the frequency of sampling or increasing the number of sampling stations based on results. Establish verification/confirmation procedures. Ensure a quality assurance/quality control program is in place consisting of blind field duplicates and laboratory splits, sample tracking and sampling, storage and transport and analysis according to established protocols.

- Link criteria for pesticide or fertilizer detection or concentrations to a course management response such as reduction or elimination in use. Define the criteria based on thresholds of concern for toxicity (generally State Water Quality Standards for surface or ground waters) or on analytical detection limits for pesticides thought to be immobile.

- Establish baseline data for all monitoring locations to determine the presence or concentrations of any parameters of interest. Include basic parameters such as alkalinity and pH which can affect chemical transport.

- Establish the statistical methods for evaluating the data obtained and to determine the number of sample replicates or stations necessary to prove or disprove the hypotheses of transport established in (1). Focus on 'worst case' areas within the course layout based on proximity, soils, slopes or conductivity such that transport will be maximal. All other cases will be less in impact. Screen all types of stormwater quality facilities to test efficacy.

- Establish criteria for returning to baseline monitoring or golf course maintenance following a 'response event'.

- Establish criteria for remedial action to provide for worst-case results.

- Establish criteria for cessation of monitoring.

- Develop plan in consultation with King County and maximize value of baseline and post-development monitoring commitments through the master drainage plan or environmental impact statement process.

- Establish funding (generally through bonding with the County) and responsibilities for implementation of the plan and most particularly for interpretation of and response to the data.

9.6 Future Research Needs

Data generated from monitoring of golf courses should be compiled and summarized. This exercise would provide a data base for establishing the efficacy of mitigation measures to sequester or contain pesticides and fertilizers. It would also help quantify course loadings to off-site resources given typical management chemical applications for the Northwest climate. Such a database would allow more precise definition of necessary mitigation measures and minimum requirements for mitigating facilities. It would also suggest necessary approaches or changes in management strategies. The monitoring plan approach recommended in Section 9.5 is intended to provide the needed data over time. These data should be made generally available for analysis.

Golf Course-Specific Stormwater Quality Facilities

While a number of conventional (swales, wet ponds and artificial wetlands) and some nonconventional (peat/sand filters, controlled "depth to till" to maintain interflow and combination rough/swales or rough/filter strips) water quality facilities have been discussed in Chapter 9, there has been no attempt to prioritize them beyond indicating the emphasis in the King County Surface Water Desi Manual. To a large extent, movement of golf course management chemicals away from fairways, tees and greens via surface or subsurface movement of stormwate or irrigation water is better managed by source control than interceptic Integrated Pest Management plan implementation and the overall golf course management plan are two methods whereby source control is implemented. Giv that management chemicals will be used, selections of those chemicals (as per t considerations discussed for the IPM plan) becomes the second priority for off course transport control. Stormwater facilities are the third tier and should designed for maximum prevention of chemical transport.

Quantitative comparison of stormwater facility alternatives for golf courses in tl Pacific Northwest is in its infancy. This is due primarily to the lack of field da collected under Pacific Northwest geologic and climactic conditions for potentia management chemicals. While nitrate transport from fertilizers can be simulat well with existing models, the generation of nitrate from slow-release fertilize and rates of loss from the root zone to deeper saturated or unsaturated soils is not well verified. Data are virtually lacking for management pesticides, as are verifi modeling tools for their analysis. For example, for most management pesticides in the Pacific Northwest, it is unknown whether maintenance of interflow all the way to a wetland boundary is the best chemical transport prevention technique, whether interflow should only be maintained to the fairway edge and then intercepted into a swale leading to more conventional surface water facilities such as wet ponds or artificial wetlands. Similarly, it is unclear whether a peat/san filter for undertile drainage from greens is more effective for fungicide removal than a french drain release to mid-fairway and subsequent interflow transport o the course (in areas where till depth is shallow).

Courses being built today are under increased scrutiny and will generally be bui with conditions for post-construction, surface and subsurface water quali monitoring. These data should be used not only as a feedback to direct source control for the course management, but also as a data base to verify simulatio model tools for predicting the effectiveness of water quality treatment facilitie. The simulation model tools themselves need to be developed for conditions particular to the Pacific Northwest, particular to individual portions of each cour and particular to the management chemicals being proposed, to enable mo rational selection of the best stormwater treatment system. Critical to much of this analysis will be determination of the correct interflow driving mechanis (macropore theory or pre-event theory) as discussed in section 7.5. Course- and chemical compound-specific data, and region-specific simulation predictive tools will accrue as golf course management plans and post-development modeling dat accumulate in King County. They should be summarized and used to prioritize approaches for stormwater (surface and subsurface) management in the future.

10.0 References

10.1 Bibliography

Abrams, R. 1991. Toxic Fairways: Risking Groundwater Contamination from Pesticides on Long Island Golf Courses. State of New York Attorney General.

Anonymous. 1990. Crop Protection Chemicals Reference. John Wiley and Sons, America.

Anonymous. 1991. Turf and Ornamentals Chemicals Reference. John Wiley and Sons, America.

Audubon Cooperative Sanctuary Program for Golf Course. Date unknown. USGA.

Ball, J., and P. Marsean. 1991. Establishing Monitoring Routines and Action Thresholds for a Landscape IPM Service. J. Arboriculture 17:88-93.

Balogh, J.C. and W.J. Walker, eds.. 1992. Golf course management and construction. Environmental Issues. Lewis Publishers. Chelsea, Michigan.

Balogh, J.C., and J.L. Anderson. 1992. Environmental Impacts of turfgrass pesticides. in J.C Balogh and W.J. Walker (eds.) Golf Course Management and Construction: Environmental Issues. Lewis Publishers, America.

Balogh, J.C., and J.R. Watson, Jr. 1992. Role and conservation of water resources. in J.C Balogh and W.J. Walker (eds.) Golf Course Management and Construction: Environmental Issues. Lewis Publishers, America.

Balogh, J.C., et al. 1992. Background and overview of environmental issues. In J.C Balogh and W.J. Walker (eds.) Golf Course Management and Construction: Environmental Issues. Lewis Publishers, America.

Balogh, J.C., G.A. Gordon, S.R. Murphy and R.M. Teitge. 1990. The use and potential impacts of forestry herbicides in Maine. 89-12070101. Final Report. Maine Department of Construction. 237 pp.

Beach, R. January 1992. Wetlands as a Priority Habitat. Washington Department of Wildlife.

Beard, J.B. 1973. Turfgrass: Science and Culture. Prentice-Hall Publishers, America.

Beard, J.B. 1982. Turf Management for Golf Courses. Burgess Publisher America.

Beven, K. J. and P. Germann. 1982. Macropores and Water Flow in Soils. Wat Resources Research, 18 (5): 1311-1325.

Bingham, E., R.P. Trosset, and D. Warshawsky. 1979. Carcinogenic Potential (Petroleum Hydrocarbons. Journal of Environmental Pathology and Toxicology 3: 483-563.

Bio-Integral Resources Center, 1991. Least-Toxic Pest Management Publications Catalogue, July.

Brauen, Stanton E. and Gwen K. Stahnke. 1992. Quantification and Fate of Nitrogen from Amended and Trafficked Sand Putting Green/Tee Profiles. pp 7-11 In Technical Report #92-3, 1992 Turfgrass Field Day, Department or Crop and Soil Sciences, Washington State University, Puyallup, WA 98371.

Carsel, R.J., C.N. Smith, J.T. Mulkey, J.D. Dean and P. Jowise. 1984. User's manual for the pesticide root zone model (PRZM). Release 1. EPA-600/3-84 109. U.S. Environmental Protection Agency, Athens, GA. 216 pp.

Castille, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S Mauermann, T. Erickson, S.S. Cook. 1992. Wetland Buffers: Use an Effectiveness. Adolfson Associates, Inc., Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, Pub No. 92-10.

Clark, Robert M., Symons, M., Ireland, J.C. 1986. Evaluating Field Scale GA(Systems For Drinking Water. Journal of Environmental Engineering, Augus 1986, pps. 744-756.

Cohen, S.Z. 1990. The Cape Cod study. Golf Course Management, 59: 26-44.

Cohen, S.Z., S. Nickerson, R. Maxey, A. Dupuy and J.A. Senita. 1990. A groun water monitoring study for pesticides and nitrates associated with golf courses on Cape Cod. Ground Water Monitoring Review, 0(1): 160-173.

Conover, M.R. 1985. Alleviating Nuisance Canada Goose Problems Through Methiocarb-Induced Aversion Conditioning. Journal of Wildlife Management 49 (3): 631-636.

Cross, A. Date Unknown. Species and Habitat, The Analysis and Impoverishmen of Variety.

DeWaters, Jan E. and Francis A. DiGiano. 1990. The Influence of Ozonated Natural Organic Matter on the Biodegradation of a Micropollutant in a GAC Bed. Journal of American Water Works Association. August, 1990, pps. 69-75.

Ecology, 1991. Draft Stormwater Management Manual for the Puget Sound Basin.

Ecology, 1992. Stormwater Management Manual for the Puget Sound Basin.

Ecology. 1992a. Biofiltration Swale Performance, Recommendations, and Design Considerations, Publication #657.

EPA Press Release, 1992. Darlene Hill, Communications Branch, Office of Pesticide Programs - Dated October 9, 1992, United States Environmental Protection Agency.

Environmental Protection Agency. 1985. Hazard Evaluation Division, Standard Evaluation Procedure, Acute Toxicity Test for Freshwater Fish. EPA-540/9-85-006. U.S. Environmental Protection Agency, Washington, D.C.

Environmental Protection Agency. 1988. Pesticides of concern in the Puget Sound Basin: A review of contemporary pesticide usage. Puget Sound Estuary Program, Final Report TC-3338-32. U.S. Environmental Protection Agency, Region X - Office of Puget Sound. Seattle, Washington.

EPA News Notes. Dec. 1990 #9. Golf Courses.

Fordham, M. Date Unknown. Conservation Management on Golf Courses J. Sports Turf Res. Inst., Vol 64.

Goldstein, E., and M. Groos, R. DeGraaf 1982/1983. Wildlife and Greenspace Planning in Medium-Scale Residential Development. Urban Ecology, 7 (1982/1983) 201-214.

Graese, Sandra L., V.L. Snoeyink, and R.G. Lee. 1987. Granular Activated Carbon Filter-Adsorber Systems. Journal of American Water Works Association. December 1987. pps. 64-74.

Green, B.H., I.C. Marshall. May 1986. An Assessment of the Role of Golf Courses in Kent, England, in Protecting Wildlife and Landscapes. Landscape and Urban Planning, 14 (1987) 143-154.

Horner, R.R. 1988. Biofiltration systems for storm runoff water quality control. Prepared for Ecology, METRO, King County and the Cities of Bellevue, Mountlake Terrace and Redmond.

Horsley, S.W. and J.A. Moser. 1990. Monitoring ground water for pesticides at golf course - A case study on Cape Cod, Massachusetts. Ground Wat Monitoring Review, 59: 101-108.

Howard, P.H. (ed.). 1991. Handbook of environmental fate and exposure dat for organic chemicals. Vol. 3. Pesticides. Lewis Publishers, Chelsea, MI. 684 pp.

Jury, W.A., D.D. Focht and W.J. Farmer. 1987. Evaluation of pesticide groundwater pollution potential from standard indices of soil-chemic adsorption and biodegradation. Journal of Environmental Quality, 16: 422-428.

Karickhoff, S.W. 1981. Semi-empirical estimation of sorption of hydrophobic pollutants on natural sediments and soils. Chemisphere, 10: 833-846.

Kenaga, E.E. 1980. Predicted bioconcentration factors and soil sorption coefficients of pesticides and other chemicals. Ecotoxicology an Environmental Safety, 4: 26-38.

Kenaga, E.E. and C.A. Goring. 1980. Relationship between water solubility, so sorption, octanol-water partitioning, and concentration of chemical in biota. i Eaton, J.G. et al. (eds.) Aquatic Toxicology, ASTM STP 707. American Society for Testing and Materials, Philadelphia, PA, pp. 78-115.

Kendall, R. J., L.W. Brewer, R, R. Hitchcock and J. R. Meyer. 1992. American Wigeon Mortality Associated with Turf Application of Diazinon AG50C Journal of Wildlife Diseases 26(2):263-267.

Kendall, R. J. and J. Ackerman. 1992. Terrestrial Wildlife Exposed t Agrochemicals: An Ecological Risk Assesment Perspective. Environmental Toxicology and Chemistry 11:1727-1749.

King County Environmental Division. Date Unknown. Wildlife Habitat Network in East Sammamish Community Planning Area.

King County, 1990. King County Surface Water Design Manual.

Klein, R.D. 1990. Protecting the Aquatic Environment from the Effects of Go Courses. Community & Environmental Defense Associates.

Leslie, A.R. 1989. Development of an IPM program for turfgrass. in A.R. Lesli and R.L Metcalf (eds.) Integrated Pest Management for Turfgrass and Ornamentals. U.S.E.P.A. Press, America.

Malear, Erik and David Farabee, Date unknown, Practical Aspects of Granular Activated Carbon Filtration For the Removal of EDB from Drinking Water.

McCall, P.J., D.A. Laskowski, R.L. Swann and H.J. Dishburger. 1981.Measurement of sorption coefficients of organic chemicals and their use in environmental fate analysis, in Test Protocols for Environmental Fate and Movement of Toxicants. Association of Official Analytical Chemists, 94th Annual Meeting. Arlington, VA, pp. 89-109.

Mehrle, P.M. et al 1987. Toxicity and Bio Concentration of 2,3,7,8-Tetrachloro-dibenzo-P dioxin and 2,3,7,8 Tetrachlorodibenzofuran in Rainbow Trout. Environmental Toxicology and Chemistry 27:47-62.

McCall, P.J., D.A. Laskowski, R.L. Swann and H.J. Dishburger. 1983. Estimation of environmental partitioning of organic chemicals in model ecosystems. Residue Revue, 85: 231-244.

Metro. 1982. Toxicants in Urban Runoff. Metro Toxicant Program Report No. 2, Water Quality Division, December 1982.

Mitsch, W.J., and J.G. Gosseling. 1986. Wetlands. Van Nostrand Reinhold, New York, N.Y.

Murphy, S.R. 1990. Aquatic Toxicity Information Retrieval (AQUIRE): A Microcomputer Database. System documentation. Spectrum Research Inc., Duluth, MN. 37 pp.

Murphy, S.R. 1992. Aquatic and terrestrial toxicity tables. in Balogh, J.C. and W.J. Walker, eds. Golf Course Management and Construction. Environmental Issues. Lewis Publishers. Chelsea, Michigan. Chapter 8.

Nakhla, G., Qubaih, J. Abu-Zaid, N., and Abdulappa, M. 1990. Impact of Nitrogen on the Adsorptive Capacity of Activated Charcoal. Environmental Technology Vol 11, pps. 731-738.

Nash, R.G. 1988. Dissipation from soil. in Grover, R. (ed.) Environmental Chemistry of Herbicides. Vol. 1. CRC Press, Boca Raton, FL. pp. 131-169.

Nielson, D.G. 1990 Landscape Integrated Pest Management J. Arboriculture 16:253-59.

Nus, Jeff, S.E. Brauen, and R, Goss. 1985. Various Nitrogen Fertilizers for Creeping Bentgrass Greens. Proceedings of the 39th Northwest Turfgrass Conference, Welches, OR, September 24-26.

Rao, P.S.C. and J.M. Davidson. 1980. Estimation of pesticide retention a transformation parameters required in nonpoint source pollution models. M.R. Overcash and J.M. Davidson (eds.) Environmental impact of Nonpoin Source Pollution, Ann Arbor Science Publishing, Ann Arbor, MI, pp. 23-67.

Rodhe, A. 1988. On the generation of stream runoff in till soils. Nordi Hydrology, (20):1-8.

Rottier, B., K. Roy, R. Jarvis, D. Fleury, B. Grisi, D. Spada. 1988. Evaluation of pesticide impacts on golf course wetlands and riparian habitats. in J.A. Kusla et al. (eds). Urban Wetlands. Proceedings of the National Wetlands Symposium, Oakland, CA. pp. 122-129.

Short, H. Date Unknown. Management Goals and Habitat Structure.

Soule, M.E. Summer 1991. Land Use Planning and Wildlife Maintenanc Guidelines for Conserving Wildlife in Urban Landscapes. Journal of th American Planning Association, Vol. 57, No. 3.

Spectrum Research, 1990. Environmental Issues Related to Golf Cours Construction and Management: A Literature Search and Review, 378 pages.

Springwood Associates. 1992. Port Gamble S'Klallam Wetland Inventory Report.

Stevens, M., R. Vanbianchi. 1992. Restoring Freshwater Wetlands in the Pacifi Northwest. Wetland Riparian Technical Committee, Washington Department of Ecology, In Press.

The Audubon Society of New York State. Date Unknown. Principles for Sustainable Resource Management. Environmental Report.

United States Golf Association, Golf Course Management and Construction: Environmental Issues, 1992. (Edited by James C. Balogh and William Walker) 951 pages.

USDA, SCS. 1991. SCS/ARS/CES Pesticide Properties Database.

USDA, U. S. Forest Service Pacific Northwest Region. 1988. Final EIS "Managing Competing and Unwanted Vegetation. November 1988.

USDA. 1969. Agricultural Handbook No. 332. U.S. Government Printing Office, Washington, D.C.

Vargas, J.M. Jr., D. Roberts, T.K. Danneberger, M. Otto and R. Detweller. 198? In A.R. Leslie and R.L. Metcalf (eds.) Integrated Pest Management f Turfgrass and Ornamentals. U.S.E.P.A. Press, America.

Walker, W.J., and B.B. Branham. 1992. Environmental impacts of turfgrass fertilization. in J.C Balogh and W.J. Walker (eds.) Golf Course Management and Construction: Environmental Issues.

Washington Department of Wildlife. Date Unknown. Plants for Wildlife in Western Washington.

Washington Department of Wildlife. January 1992. Washington Department of Wildlife Fish and Wildlife Data Bases.

Washington Department of Wildlife. November, 1991. Buffer Needs of Wetland Wildlife.

Washington State University Cooperative Extension. 1991. Concepts of Integrated Pest Management in Washington. Publication EB0753.

Washington State University Extension Service, 1991. Pacific Northwest Weed Control Handbook.

Washington State University Extension Service, 1991. Pacific Northwest Insect Control Handbook.

Washington State University Extension Service, 1991. Pacific Northwest Disease Control Handbook.

Washington State University Extension Service, Extension Bulletin 1129, 1984. Annual Bluegrass

Wauchope, R.D., T.M. Buttler, A.G. Hornsby, P.W.M. Augustihn-Beckers and J.P. Burt. 1991. The SCS/ARS/CES pesticide database for environmental decision-making. Review of Environmental Contamination and Toxicology, 123: 1-155.

10.2 Additional References

This bibliography includes references identified by the King County Steering Committee and the Technical Advisory Committee.

ABC Excerpted From 20/20 broadcast. 1988. Much Ado About Nothing.

Aerification of Water Hazards/Holding Ponds/Reservoirs. (No reference).

Agnew, Michael L. Groundwater, Turf Management and Public Perception. Iowa State University Turfgrass Topics/Spring 1990-91.

Agron, J. Turfgrass Evapotranspiration I - Factors Influencing Rate in Urt Environments. 75:824-30.

Akins, Tom. Study Shows Golf Maintenance Not a Danger to Groundwater.

Angle, J.S. 1989. Personal Communication. IV. Runoff and Sediment Losse from Tall Fescue (Festuca Arundinacea Shreb.) under Simulated Rainfall.

B I R C. July 1991. Least Toxic Pest Management.

Ball, J., and P. Marsan. 1991. Establishing Monitoring Routines and Action Thresholds for a Landscape IPM Service. J. Arboriculture 17:88-93.

Beard, J.B. 1991. IPM in Turf. Grounds Maintenance, pp. 26-28.

Beard, J. B. 1987. Turf Management for Golf Courses.

Beard, James B. Copyright 1982 - United States Golf Association. Golf Cour Management and Construction Environmental.

Beard, J.B. 1973. Turfgrass: Science and Culture. Englewood Cliffs, Ne Jersey: Prentice Hall, Inc.

Bio-Integral Resource Center. 1989. Integrated Weed Management for Urb Areas. Berkeley, California.

Bio-Integral Resource Center. 1991. Least-Toxic Pest Management: Lawı Berkeley, California.

Blais, Peter. Golf Course News, April 1990. Government Relations Briefing Feb/Mar 1990. Groundwater, Studies Positive for Golf.

Bolger, Alberts, and Soule. 1991. Occurrence Patterns in Habitat Fragments.

Brauen, Stanton E., Jeffrey Nus, and Roy L. Goss. Proc. 41st Northwest Turfgrass Conf., 41:135-137 1987. Nitrogen Use Efficiency on Sand.

Beard, J. B. 1988. Turfgrass Chemical Update: Herbicides, Insecticides Fungicides.

Brauen, S.E. 1988. Feeding the "Green Monster" 1988 Proc. 25th Annual Conf. Western Canada Turfgrass Assoc. 85:D1-D7.

Brauen, S.E., and J. L. Nus. 1989. Influence of Nitrogen Source on Nitroge Recovery and Quality of Creeping Bentgrass (Agrostis Stolonife `Penncross`). Proc. 6th International Turfgrass Res. Conf., Tokyo, Japan

Brauen, S.E., G.R. Stahnke, B. Johnson, G. Chastagner, C. Cogger, and R. Byther. 1991. Quantification and Fate of Nitrogen from Amended and Trafficked Sand Putting Green/Tee Profiles. Turfgrass Field Day, June 25 to 26.

Brauen, S.E., G. R. Stahnke, G. Chastagner, and R.L. Hummel. 1991. List of turfgrass Cultivars Evaluated in Western Washington, Oregon, and British Columbia During the past 10 years. Turfgrass Field Day, June 25-26.

Brauen, S.E., G. R. Stahnke, B. Johnston, G. Chastagner, and R.L. Hummel. 1991. Turfgrass Field Day, June 25-26. Quantification and Fate of Nitrogen from Amended and Trafficked Sand Putting Green/Tee Profiles.

Fisher, Brett. JPR Spr 1989. Driving Pesticides Out of Range.

Brewer, Driver, Kendall, Lacher, and Galindo. 1988. Avian Response to a Turf Application of Triumph 4E.

Business Week. March 27, 1989. The Boom in Golf as Baby Boomers Hit the Links.

CAST. 1975. The Phenoxy Herbicides. Report No. 39. Council for Agricultural Science and Technology, Ames, Iowa.

City of Lynnwood. 1989. Draft Environmental Impact Statement.

Clements, B. 1991. Dump's Neighbor's Remain Wary.

Cohen, S.Z. 1990. The Cape Cod Study. Golf Course Management.

Cohen, Stuart Z., Susan Nickerson, Robert Maxey, Aubry Dupuy, and Joseph A. Senita. GWMR Winter 1990, A Ground Water Monitoring Study for Pesticides and Nitrates Associated with Golf Courses on Cape Cod. (U.S. Environmental Protection Agency).

Cohen, S. Z. 1990. The Cape Cod Study.

Comments from Citizens for Responsible Growth. November 17, 1988.

Community of Environmental Defense Associates. 1990. Protecting the Aquatic Environmental from the Effects of Golf Courses.

Concerns of Citizens for Responsible Growth to Snohomish City Hearing Examiner. March 14, 1989.

Concerns of Citizens for Responsible Growth to Snohomish County Heari Examiner. March 14, 1989.

Conover, M. R. 1985. Adversive Conditioning in Geese.

Cook, Tom; Associate Professor, Oregon State University. July 7, 1988. Golf Course Chemical Use.

Cook, Thomas W. Oregon State University, Far West Show 1990. Are Golf Courses Polluting Our Environment?

Cooke, G.D., E.G. Welsh, S.A. Peterson, P.R. Newroth. 1986. Lake an Reservoir Restoration. Butterworths Public. Boston. 392 pp.

Cooper, Richard J., U. Mass Amherst. Golf Course Management Feb. 199 Evaluating the Runoff and Leaching Potential of Turfgrass Pesticides.

Cooper, Dr. R. J. 1987. Turfgrass Pesticide Risk in Perspective.

Cox, Caroline. JPR Fall 1987. Will That Pesticide Leach?

Cox, C. 1987. Journal of Pesticide Reform 7:14-15. Pesticide Basics #3 Will th Pesticide Leach?

Cox, Caroline. JPR Fall 1987. Will That Pesticide Leach?

Cross, A. 1990. The Analysis and Impoverishment of Variety.

Culp, R. L. and R. M. Clark. 1983. Granular Activated Carbon Installation American Waterworks Association Journal. 75(8):398-405.

Cultural System for a Bentgrass Putting Green, Summaries of Cultural System Date Unknown.

Daily Journal of Commerce. Seattle, WA. Nov. 15, 1991. Golf Course, Home to be Ready Next Spring.

Department of Entomology. Date Unknown. Insectary For Biological Control C Insects, Mites and Weeds.

Diamond, J. 1988. Urban Extinction of Birds.

Eastside Week. Dec. 4. 1991. Below Par.

Edmondson, J. 1987. Hazards of the Game.

Energy Conservation Criteria for Golf Course Pumping Plants. (No reference).

Environmental Protection Agency. 1989. Pesticide Fact Sheet 2-(2-methyl-4 chlorophenoxy) Propionic Acid and Its salts and Esters. 540/FS-89-031. Office of Pesticides and Toxic Substances. U.S.E.P.A. Washington, DC, U.S.

EPA Report, Chemical Applications by Region.

EPA, Office of Pesticide Programs, Field Operations Division. 1989. Integrated Pest Management for Turfgrass and Ornamentals.

EPA Pesticide Survey List, 4/14/89.

EPA. Date Unknown. Environmental Protection Agency Office of Pesticides and Toxic Substances.

Erickson, Larry E. Grounds Maintenance, Feb 1987. What You Need to Know About Groundwater Concerns.

Gold, Arthur J. et al.. Journal of Soil & Water Conservation Mar-April 1990. Nitrate-Nitrogen Losses to Groundwater from Rural and Suburban Land Uses.

Feldman, Jay NCAMP. May 9, 1991. Subcommittee on Toxic Substances.

Fisher, Brett. JPR Spr. 1989. Driving Pesticides Out of Range.

Fordham, M. 1988. Conservation Management on Golf Courses.

Fowler, H. G. and Costa, M. L. 1986. Mole Cricket Pests on South American Golf Courses.

Franklin, J.F. and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. OSU Press. 452 pp.

Fungicides: Some Help with your Decision Making. Brown II, Dr. Edward, Univ. of Georgia Park/Grounds Management 2.89.

Fushtey, S. G. and Frank, R. 1981. Distribution of Mercury Residues from the Use of Mercurial Fungicides on Golf Course Greens.

Geoffrey S. Cornish & William G. Robinson. Date Unknown. Golf Course Design: An Introduction. North Palm Beach, Fl. National Golf Foundation, n.d.

Gold, Sullivan, Hanson and Morton. 1988. The Effect of Lawn Care Practices Groundwater.

Gold, A. J., W. M. Sullivan, and R. J. Hull. 1989. Influence of Fertilization a Irrigation Practices on Water-Borne Losses from Turfgrasses. Contribution No. 2445, University of Rhode Island Agriculture Experiment Statio Kingston, RI.

Gold, A.J., W.M. Sullivant, and R.J. Hull. 1989. Influence of Fertilization ar Irrigation Practices on Waterborne Nitrogen Losses from Turfgrass Integrat Pest Management for Turfgrass and Ornamentals. Washington, D.C.: U.S. EPA.

Gold, A. J., T. G. Morton, W. M. Sullivan, and J. McClory. 1988. Leaching of 2,4-D and Dicamba from Home Lawns. Water, Air and Soil Pollutio 37(1988):121-129.

Goldstein, E. L. 1983. Wildlife and Greenspace Planning in Medium-Sca Residential Developments.

Golf Driving Range Manual: "North Palm Beach, FL 1978" 1979. Golf faciliti in the United States. 1961.

Golf Operators Handbook. The Par 3 and Executive Golf Course Planning an Operating Handbook.

Date Unknown. Planning and Building the Golf Course. "Planning the Gol Course Maintenance Building". Information sheet GC-27.

Goss, R.L. 1982. Tank Mixing Herbicides. Northwest Turfgrass Topics.

Goss, D., and R.D. Wauchope. 1990. The SCS/ARS/CES Pesticide Propertie Database: II, Using It with Soils Data in a Screening Procedures, in Pesticide in the Next Decade: The Challenges Ahead, proceedings in the Third National Research Conference on Pesticides. D.L.Weigmann (Ed.), Nov. 8-9, 1990, p 471-493.

Goss, R.L. 1987. Turfgrass and Soil Irrigation Needs in Review. Proc. 41s Northwest Turfgrass Association Conf. 41:16-20.

Goss, R. L. 1989. Construction and Maintenance of The Falls Golf Cours Mercer Island, Washington: Prescription Turf Services, Inc.

Goss, R. L. 1988. Managing Bentgrass on Trees, Greens and Fairways.

Grant, M.D. 1989. Integrated Pest Management in the Golf Course Industry. A case study and some general considerations. Integrated Pest Management for Turfgrass and Ornamentals. Washington, D.C: U.S. Environmental Protection Agency.

Grant, Z. 1987. Groundwater Issues in Pesticide Regulation.

Green, & Marshall. 1987. An Assessment of the Role of Golf Courses in Kent, England in Protecting Wildlife and Landscapes.

Gup, Ted. 1991. National Wildlife, Getting at the Roots.

Haggard, J. March 7, 1991. The Farm Golf Club.

Hammer, D.A. ed. 1990. Constructed Wetlands for Wastewater Treatment. Lewis Public. 831 pp.

Hanson, A.A., and F.V. Juska. 1969. Turfgrass Science. Madison, Wisconsin: American Society of Agronomy.

Harding Lawson Associates. 1991. Seattle, Washington. Predicted Water Quality Impacts from the Proposed Sea Van Golf Course.

Harestad and Keisker. 1988. Nest Tree Use by Primary Cavity-nesting in BC.

Harivandi, M. 1987. Water Limited? Save It! Proc. 41st Northwest Turfgrass Association Conf. 41:31-40.

Eckhoff, Harry C. Public Works, July 1978. "Guidelines for Planning and Building a Golf Course".

Hegstrom, E. 1991. Below Par.

Herrera Environmental Consultants, Inc. 1989. Integrated Pest Management Plan for The Falls Country Club, Seattle, Washington.

Herrera Environmental Consultants. 1989. Integrated Pest Management Plan for The Falls Country Club.

Herrera Environmental Consultants. August 31, 1989. Integrated Pest Management Plan for the Fall County Club.

Holtzmann, O.V., R K Nishitasto, C.L. Murdock and W.C. Mitchell. 1991. Integrated Pest Management Program for Liki Lani Golf Course.

Houck, M. 1991. Heron Lakes Golf Course.

Hummel, N. W. 1988. Controlling Moss on Golf Course Greens.

Hunton, B. 1990. Aberdeen Pit Golf Course Pesticide Site.

Jacob, Irv Pres. International. Seed Co., Salem, OR. Hard Fescue for Lo Maintenance Turfgrass Seed. Park/Grounds Management 2/89.

James A. Watkins. Turf Irrigation Manual.

John Strawn. July/Aug. 1989. Voluptuous Earth Desmond Muirhead Launches Golf's Post. Modern Era.

Johnson, G. D. and Mulla, M. S. 1982. Suppression of Nuisance Aquatic Midges

Johnson, D. 1991. Appropriate Plants for Northwest Landscapes Alternatives.

Johnson, D. 1990. Lawn Care Alternatives.

Johnson, D. 1988. Low Chemical Lawn Care.

Journal American. Bellevue, WA. Bear Creek Northshore will Swell, Report Predicts.

Journal of Pesticide Reform. Fall 1991. Golf Course Pesticide Use.

Karla L. Heuer. Golf Courses - A Guide to Analysis and Valuation.

King County. 1990. King County Golf Course Preservation Committee Repo on Golf Courses.

Kriner, Richard E. AARP and EPA April, 1985. Final Report on Results National Survey of Pesticide. Usage on Golf Courses in U.S.

Kriner, Richard E. A National Survey of Pesticide Usage on Golf Courses in tl U.S.

Lazell, J. 1989. Pushy Wildlife.

Leslie, A.R. 1989. Development of an IPM Program for Turfgrass. Integrat Pest Management for Turfgrass and Ornamentals. Washington, D.C:US.EP

Leslie, Mark. Golf Course News, April 1990. Jones: Industry Must Fig Misconceptions.

Lori, Parks, Planning and RD. April 30, 1991. Planner's Forum - Negative Impacts on Golf Courses.

Maclean's. May 21, 1990. The Greening of Golf.

Manufacturer's Data Sheets on Rainbird Max V or Toro Network 8000 Computer-controlled Irrigation Systems.

Marsh, P. C. and Luey, J. E.. 1982. Oases for Aquatic Life Within Agriculture Watershed.

Matsumura, F., and C.R. Krishna Murti(eds). 1982. Biodegradation of Pesticides. New York, New York: Plenum Press.

McCarty, Roberts, Miller and Brittain. 1990. An Integrated Plant Management Project for Turfgrass.

Melear and Farabee. Date Unknown. Removal of EDB From Drinking Water.

Miller, M. S. 1987. The Golf Course Superintendent and the Environmentalist Friends or Foes?

Monroe, Dave. January 30, 1991. Golf Course Chemicals.

Monroe, Dave. January 30, 1991. Golf Course Chemicals.

Montgomery, N. 1991. Golf Course Ideas for Landfill Tees Up Again.

Montgomery, N. (Seattle Times). 1991. Evapotranspiration (news article).

Morton, T. G., A. J. Gold, and W. M. Sullivan. 1988. J. Environ. Qual. 17(1):Jan.Mar., 1988.

Morton, T. G. Journal of Environmental Quality Vol. 17, No. 1, 1988. Influence of Overwatering and Fertilization on Nitrogen Losses from Home Lawns.

Muirhead, Desmond. Urban Land Institute, 1970. "Building the Golf Course".

Mullison, Dr. W. R. Date Unknown. The Industry Task Force on 2, 4-D.

Nancy A. Ryan & Company. August 4, 1990. Twin Rivers Golf Course, L90CU014 & L90SH070.

Naqvi, S.M., and T.S. Leung. 1983. Trifluralin and Oryzalin Herbicid Toxicities to Juvenile Crawfish and Mosquito Fish. Bull. Environ. Conta... Toxicol, V.31, p.304-308.

NCAMP Letter to Patrinka Kelch and General Letter to Citizens. August 2ı, 1987.

NCAMP Letter to Patrinka Kelch, 8/21/87 and general letter to citizens.

NCAMP. August 1987. Golf Courses: Turf, Tees and Toxins, Pesticides an You.

NCAMP. August, 1987. Golf Courses: Turf, Tees and Toxins, Pesticides an You.

Nebraska Cooperative Extension Service. Turfgrass Disease Damage Preventio... and Control EC81-1235.

Nebraska Cooperative Extension Service. Turfgrass Weed Identification an... Control EC83-1241.

Nebraska Cooperative Extension Service. Turfgrass Insect Damage Preventio... and Control EC81-1238.

Neeley, D., and G.K. Smith. 1991. IPM Strategies Used by Arborists. J. Arboriculture 17:8-12.

Nielsen, D.G. 1990. Landscape Integrated Pest Management. J. Arboriculture 16:253-59.

Niemczyk, H. D. Filary, Z. and Krueger, H. 1988. Movement of Insecticid Residues in Turfgrass Thatch and Soil.

No Name. Date Unknown. Snohomish Environmental Checklist.

No Name. Date Unknown. EPA Report, Chemical Applications by Region.

No name. April 14, 1988. EPA Pesticide Survey List.

No Name. Date Unknown. Summary Information on the Toxicology o Pesticides. Proposed for Use at a Shepardstown, WV Golf Course Site.

Northwest Coalition for Alternatives to Pesticides (NCAP). 1991. Because Our World Is Too Precious To Poison.

Northwest Coalition for Alternatives to Pesticides (NCAP). 1991. Information Services.

November, J. 1988. Runoff and Ground Water Contamination.

Nus, Jeff, Stanton Brauen, and R. L. Goss. 1985. Various Nitrogen Fertilizers for Creeping Bentgrass Proc. 39th Northwest Turfgrass Conf. 39:63-71.

Obermann, D. 1991. Horticultural Waste Dilemma Spurs Interest in PGRs. Lawn and Landscape Maintenance. 46-49 pp.

Petrovic, A. M. 1990. The Fate of Nitrogenous Fertilizers Applied to Turfgrass. J. of Env. Qual. 19:1-14.

Petrovic, A.M. 1990. The Fate of Nitrogenous Fertilizers Applied to Turfgrass. J. of Env. Qual. 19;1-14.

Petrovic, A. Martin. PhD Cornell University, Landscape Management May, 1988. Late Fall Fertilizing & Groundwater Quality.

Petrovic, A. M. 1990. The Fate of Nitrogenous Fertilizers Applied to Turfgrass.

Potter, D. A. 1987. Ecological Side Effects of Pesticide and Fertilizer Use on Turfgrass.

Potter, D.A., and K.S. Braman. 1991. Ecology and Management of Turfgrass Insects. Annu. Rev. Entomol 36:383-406.

Potter, Daniel A. Univ. of Kentucky, Dept. of Entomology, Turfgrass Topics/Spring, 1990-91. Ecological Side-Effects of Pesticide and Fertilizer Use on Turf. Source: NYSTA Spring '90 Bulletin 138.

Powers, R. 1990. Cutting Chemical Use Keeps Cash Box Green.

Prepared by Richard E. Kriner, AARP and EPA. April 1985. Final Report on Results of National Survey of Pesticide Usage on Golf Courses in U.S.

Puget Sound Water Quality Authority. 1990. Issue Paper: Pesticides in Puget Sound.

Puget Sound Business Journal. July 23, 1990. Fore Golf Course Buyers Crowd Tee. Vol II, No. 10.

Pullman, Washington. Washington State University, Cooperative Extension. Herbicides and Water Quality KC139.

R.W. Thorpe & Associates, Inc. 1990. Tri-Land - The Farm Golf Cl
Addendum to Final Environmental Impact Statement of Alderra Properti
Prepared for King County Building and Land Development.

Rainbird or Toro Data Sheets on Weather Stations. (No reference).

Rainfall-Evaporation Data Booklet. Published by Toro Mfg.

Real Estate Investing Newsletter. Jan. 1979. "Investing in Golf Course".

Rees L. Jones & Guy L. Rando. 1974. Golf Courses Developments.

Reeve, N. J. and Morris, P. A. 1985. Summer Nests by the Hedgehog.

Rhea, A. 1991. PGA Unveils Design For New Golf Course (news article).

Robert Trent Jones Jr. & Jack Nicklaus. 1988. Great Golf Courses.

Roberts, E. C. Date Unknown. "Organic" Turf Management.

Ronald W. Fream. Urban Land, March 1978. "Great Green Monster or Jol
Green Giant?". "How to Prevent Golf Course Maintenance Headaches
Resort Management, May 1978. "Symbiosis: A Method of Minimizing Gol
Course Maintenance Cost." Southern Golf, Spring 1979.

Rottier, Roy, Jarvis, Fleury, Grisi, and Spada. 1988. Evaluation of Pesticid
Impacts on Golf Course Wetlands and Riparian Habitats.

Rottier, B., K. Roy, R. Jarvis, D. Fleury, B. Grisi, and D. Spada. 1988
Evaluation of Pesticide Impacts on Golf Course Wetlands and Ripari
Habitats. Pages 122-120 in: Kuslet, J.A., S. Daly and G. Brooks (eds.),
Urban Wetlands, proceedings of National Wetlands Symposium, June 26-29
1988. Oakland, CA.

Sanders, Patricia L. Penn. State Univ. Management of Fungicide Resistanc
Nor-Am Turf Management Report, Vol. 1, No. 2.

Schmidt, James C. (Ed). 1990. How to Identify and Control Water Weeds ar
Algae. Applied Biochemists, Inc. Mequon, Wisconsin.

Schneider, K. 1991. Senate Panel Says Lawn Chemicals Harm Many.

Schwab, R. 1990. Denver Post, New Product Keeps Grass Greener at Gol
Courses.

Sears, M. K. Dislodgeability of Insecticides Applied to Turfgrass.

Seattle PI. March 14, 1990. Private Golf Fees Soar Like Tee Shots.

SEPA Hearing, Daryl Scheibel Testimony. March 14, 1989.

SEPA Hearing, Daryl Scheibel Testimony. March 14, 1989.

Shapiro and Associates, Inc. January 1991. Proposed Remington Golf Course.

Shapiro and Associates, Inc. March 1991. Proposed Remington Golf Course.

Shapiro and Associates, Inc. 1990. Environmental Monitoring Program for the Proposed Remington Golf Course, prepared for Covington Creek.

Shapiro and Associates, Inc. Seattle, Washington. 1990. Site Management Manual for the Proposed Remington Golf Course.

Short, H. L. Date Unknown. Management Goals and Habitat Structure.

Smiley, R.W. 1987. Lawn Diseases and Control Options Proc. 41st Northwest Turfgrass Association Conf. 41:54-57.

Smith, G.J. (Ed). 1987. Nottingham, England. Agrichemicals Handbook, Second Edition. Royal Society of Chemistry Information Services.

Soden, L. 1992. Setting Up an IPM Program for Outdoor Ornamentals. Presentation for Washington State Department of Agriculture Pesticide Recertification Program, Feb. 4, Lynnwood, WA.

Soule, M. E. 1991. Land Use Planning and Wildlife Maintenance.

Sports Turf. Feb. 1, 1988. Research Reveals Accelerated Breakdown of Pesticides

Stahnke, Dr. and Brauen, Dr. WSU-Puyallup. Date Unknown. Current Status of Turfgrass IPM Research.

Stahnke, G., and S. Brauen. 1991. European Cranefly Larvae Control. Turfgrass Field Day, June 25-26.

Stahnke,G., and S. Brauen. 1991. European Cranefly Larvae Control. Turfgrass Field Day, June 25-26.

Standard Specifications for Construction of Water, Sewer and Reclaimed Wat Facilities Irvine Ranch Water District.

Stone, W. B. and Knoch, H. 1982. American Brant Killed on Golf Courses t Diazinon.

Stratton, Dayle Ann. April, 1992. Protecting Groundwater: A Strategy fo Managing Agricultural Pesticides and Nutrients. Washington State Department of Ecology, Water Quality Program.

Summary Information on the Toxicology of Pesticides Proposed for Use at a Shepardstown, WV Golf Course Site.

Sweeney, J. M. 1984. Analysis of White-Tailed Deer Use of Forest Clear-cuts.

Tanigoshi, L. Rearing Armies of Insects to Fight Farm Pests.

Tatnall, T. W. 1991. How Green is Your Golf Course?

The Seattle Times. January 6, 1992. County Seeks Golf - Course Consensus.

The Seattle Times. August 7, 1990. Take a Swing at These 9.

The University of California, Michigan State University, and Oregon Stat University. Cooperative Extension Offices of Cornell University. EXTOXNET, Extension Toxicology Network, 1991.

Troutman, Ph.D. B. C. 1988. The Lawn Technician.

Troutman, Ph.D. B. C. 1986. EPA Decides Not To Review, 2, 4-D.

Turfgrass Field Day Pamphlet, June 24-25. 1986. Nitrogen Sources for Maintenance of 'Penncross' Creeping, Bentgrass Greens.

U.S. Golf Association, Green Section. Far Hills, NJ. 1989. Specification for Method of Putting Green Construction.

U.S. House of Reps. May, 1991. Statement of Jay Feldman to NCAMP to Ag Committee.

U.S. Department of Agriculture, Soil Conservation Service, and Washington Stat Cooperative Extension Service. 1985. The State of Washington Irrigation Guide. Spokane, Washington.

U.S. EPA News - Notes. 1990. Parkway Began as a Golf Course.

U.S. Environmental Protection Agency (EPA) Pesticide Fact Sheets for: Chlorothalomil (1988), Dicamba (1983), Fenoxaprop-ethyl (1988), Glyphosate (1986), Mancozeb (1987), MCPA (1989), MCPP (1988), Pronamide (1986), and Thiophanate-Methyl (1988).

U.S. EPA. August, 1989. Integrated Pest Management for Turfgrass and Ornamentals.

University of California, Cooperative Extension. Aquatic Pest Control Pesticide Application Compendium. 1: The Safe and Effective Use of Pesticides.

University of California, Cooperative Extension. 1980. Know your Turfgrasses.

University of California, Cooperative Extension. 1987. Fate of Pesticides in the Environment.

University of California, Cooperative Extension. 1988. Guide to Turfgrass Pest Control.

University of California, Cooperative Extension. 1977. Ornamental and Turfgrass Pest Control

University of California, Cooperative Extension. 1973. Lawn Aeration and Thatch Control.

University of California, Cooperative Extension. 1989. Turfgrass Pests.

University of California, Cooperative Extension. 1977. Ornamental and Turfgrass Pest Control.

University of California, Cooperative Extension. 1985. Turfgrass Water Conservation.

University of Maryland, unpublished manuscript. Personal Communication. III. Nutrient and Sediment Losses from Turfgrasses.

Unknown. Date Unknown. Nutrition Survey Results (Fertilizer Analysis).

Unknown. Date Unknown. Notes on Lawn Care.

USA Today. November 7, 1991. "Ladies Professional Golf Association Learns Realities of Breast Cancer".

USGA Green Section Record. Far Hills, NJ. 1991. Index Vol. 15, No. 1 1977 - Vol. 29, No. 6, 1991.

USGA Green Section Record. Far Hills, NJ. Index Vol. 15, No. 1 1977 - V
29, No. 6 1991.

USGA Green Section Record. Far Hills, NJ. 1991. Index Vol. 15, No. 1 1977
Vol. 29, No. 6, 1991.

USGA Green Section Record. 1991. Far Hills, NJ. Index Vol. 15, No. 1 1977
Vol. 29, Nol 6, 1991.

USGA Green Section Record. Index Vol. 15, No. 1 1977 - Vol. 29, No. 6, 199
Fall Hills, NJ, 1991.

USGA Green Section Record. Index Vol. 15, No. 1, 1977 - Vol. 29, No. 6, 1991
Far Hills, NJ 1991.

USGA. Date Unknown. Audubon Cooperative Sanctuary Program.

Vargas, J.M., Jr. et al. 1989. Biological Management of Turfgrass Pests and th
Use of Prediction Models for More Accurate Pesticide Applications.
Integrated Pest Management of Turfgrass and Ornamentals. Washington, D.C.
U.S. EPA.

Varner, Grisso, and Shearman. 1990. Calibration Accuracy of Golf Course
Pesticide Applicators.

W.S.D.A. 1990. Washington Re-registration List of Pesticides.

W.S.D.A., Pesticide Management Division. 1990. Pesticide Laws and Rules.

Waddington, D. V. 1987. Proceedings of the 25th Annual North Carolin
Turfgrass Conference.

Washington State University, Cooperative Extension. Pullman, Washington
Concepts of Integrated Pest Management in Washington EB0753.

Washington State University, Cooperative Extension. Pullman, Washington.
Turfgrass Diseases Supplement EB0713S.

Washington State University, Cooperative Extension. Pullman, Washington.
Thatch and its control EB1117.

Washington State University, Cooperative Extension. Pullman, Washington.
Turfgrass Diseases EB0713.

Washington State University, Cooperative Extension. Pullman, Washington. Irrigation Scheduling PNW288.

Washington Department of Ecology. 1991. Public Draft Stormwater Management Manual for the Puget Sound basin.

Washington State University, Cooperative Extension. Pullman, Washington. Home Lawns EB0482.

Washington State University, Cooperative Extension. Pullman, Washington. Construction and Maintenance of Natural Grass Athletic Fields PNW0240.

Washington State University, Cooperative Extension. Pullman, Washington. Simple Irrigation Scheduling Using Pan Evaporation EB1304.

Washington State University. June 25 & 26, 1991. 1991 Turfgrass Field Day

Washington State University, Cooperative Extension. Pullman, Washington. Sprinkler Irrigation - Application Rates and Depths EB1305.

Washington State University, Cooperative Extension. Pullman, Washington. Turfgrass Seeding Recommendations for the Pacific Northwest PNW0299.

Washington State University, Cooperative Extension. Pullman, Washington. Fertilizer Guide: Western Washington FG0041.

Washington State University, Cooperative Extension. Pullman, Washington. European Crane Fly EB0856.

Washington Toxics Coalition to Council Members. Snohomish County. May 11, 1989.

Washington State University, Cooperative Extension. Pullman, Washington. 1991. Pacific Northwest Weed Control Handbook.

Washington State University, Cooperative Extension. Pullman, Washington. Washington Pesticide Laws and Safety MISC 0056.

Washington Toxics Coalition (WTC) to Peter Donohue, Hearings Examiner. Snohomish County. March 14, 1989.

Washington Toxics Coalition to George Newman, Senior Planner. Snohomish County. January 13, 1989.

Washington State University, Cooperative Extension. Pullman, Washington. R of Lime in Turfgrass Management EB1096.

Washington State University, Cooperative Extension. Pullman, Washingtor Aquatic Pest Control MISC0134.

Washington State University, Cooperative Extension. Pullman, Washingtc 1991. Pacific Northwest Insect Control Handbook.

Washington Toxics Coalition to Peter Donohue. March 14, 1989. Hearin Examiner, Snohomish County.

Washington State Department of Health, Toxic Substances Fact Sheet. 198 Organophosphate Insecticides.

Washington Department of Health, Toxic Substances Fact Sheet. 198 Pesticides.

Washington State Department of Wildlife. 1991. Buffer Needs of Wetla Wildlife.

Washington State University, Cooperative Extension. Pullman, Washingto Pesticide Movement in Soils-Groundwater EB1543.

Washington State University, June 25 & 26. 1991 Turfgrass Field Day.

Washington Toxics Coalition. Date Unknown. Working to Reduce Society Reliance on Toxic Chemicals.

Washington State Department of Health, Environmental Health Program Pesticide Section. Pesticide Incident Reporting and Tracking Review Panel, Annual Report 1991,

Washington State Univ., Cooperative Extension. Pullman, Washington. 1991. Pacific Northwest Disease Control Handbook.

Watschke, Dr. T. L. 1986. The Future of Turfgrass Management and Underground Water Quality.

Watschke, T. L. and Mumma, R. O. Date Unknown. Penn State Pesticide Study.

Watschke, Dr. T. L. 1986. The Future of Turfgrass Management and Underground Water Quality.

Watschke, T. L. and Harrison, S. 1988. Is Pesticide Runoff From Turf Increasing?

Watschke, T.L. et. al. Pennsylvania Turfgrass Council, Runoff From Turf as Effected by Establishment Method.

Watschke, T. L. and Harrison, S. 1988. Is Pesticide Runoff From Turf Increasing?

Watschke, Thomas L., and Mumma, Ralph O. Date Unknown. The Effect of Nutrients and Pesticides Applied to Turf on the Quality of Runoff and Percolating Water. Penn State Environmental Resources Research Institute, Departments of Agronomy and Entomology, Final report for US Department of the Interior, Geological Survey, ER8904

Watschke, Thomas L. Penn. State University. Golf Course Management Feb. 1990. The Environmental Fate of Pesticides.

Watschke, Thomas L. Turfgrasses Can Safely Clean Our Water Supplies, A Scientific Viewpoint.

Weis, J. S. 1984. A Rapid Change in Methylmercury Tolerance in a Population of Killfish from a Golf Course Pond.

Welterlen, M.S., C.M. Goss, J.S. Angle, and R.L. Hill. 1989. Surface Runoff from Turf. Integrated Pest Management for Turfgrass and Ornamentals.

Western Landscaping News. June 1978. "Water on the Golf Courses".

Wilbur-Ellis. Disease Control Guide.

Wilkinson, J. 1980. Understanding Slow-Release Nitrogen. Northwest Turfgrass Topics.

Wilson, E. 1989. Threats to Biodiversity.

WTC to Council Members. Snohomish County. May 11, 1989.

WTC to George Newman, Sr. Planner. Snohomish County. January 13, 1989.

10.3 Washington State University, Puyallyap Research and Extension Center, Publication List

Refereed Journal Publications:

Brauen, Stanton E., Roy L. Goss, and A. Douglas Brede. 1993. Registration of 'Putter' Creeping Bentgrass. Crop Sci. (Accepted Oct, 1992)

Brauen, S.E., R.L. Goss, W.J. Johnston, and G.K. Stahnke. 1992. Differences in thatch development related to aerification method and intensity in bentgras turf. ITS Proceedings, West Palm Beach, FL. (Submitted abstract and research paper).

Brauen, S. E. and R. L. Goss. 1991. Annual bluegrass Seedhead Control and Reduction in Plant Discoloration with Mefluidide and Iron. (Chapter 16) In J. Kaufmann (ed.) Managing Vegetation with Chemicals. PGRSA Spec Publ. Plant Growth Regulator Soc. Amer., Ithaca, NY.

Cai, Zhongling, Stanton E. Brauen, David R. Gealy, William J. Johnston, an Thomas A. Lumpkin. 1992. Tolerance of Chinese Milkvetch (*Astragalus sinicus*) to herbicides. Weed Technology 6:104-107.

Chapman, J. E., S. E. Brauen, G. K. Stahnke, and W. Johnston. 1992. Comparison of nitrate ion specific electrode and rapid flow analysi techniques. ITS Proceedings. West Palm Beach, FL. (Submitted abstrac and technical paper).

Kuo, S., S. E. Brauen, and E. J. Jellum. 1992. Phosphorus availability in some acid soils influences bentgrass and annual bluegrass growth. HortScience 27(4):370.

Kuo, S., S.E. Brauen, and E.J. Jellum. 1992. The effects of aluminum and phosphate on the growth of annaul bluegrass and bentgrass in some acidi western Washington soils. Soil Sci. 153(5):365-372.

Nus, J. L. and S. E. Brauen. 1991. Clinoptilolitic zeolite as an amendment fo establishment of creeping bentgrass on sandy media. HortScience 26(2):117-119.

Stahnke, G. K., S. E. Brauen, and A. Antonelli. 1992. Control methods for European cranefly larvae. ITS Proceedings, West Palm Beach, FL (Submitted abstract and technical paper).

Abstracts:

Brauen, S. E., N.E. Jackson, G.K. Stahnke, R.L. Goss, and R. Ingram. 1992. Effect of dithiopyr and endothall on control of annual bluegrass in 'Putter' creeping bentgrass turf. p. 165. In Agron. Abstr. ASA, Madison, WI.

Brauen, S. E. and D. M. Sullivan. 1991. Nitrogen recovery from dairy slurry applications to cool season grasses. p. 283-284. In Agron. Abstr. ASA, Madison, WI.

Brauen, S. E. 1991. Selecting species for the long haul. Extended Abstract of presentation for Pacific Coast Turf and Landscape Show, Seattle, WA, December 3-4, 1991.

Brauen, S. E., J. L. Nus, R. L. Goss, and G. K. Stahnke. 1990. Testing nitrate leaching from turfgrass sand lysimeters. p. 170. In Agron. Abstr. ASA, Madison, WI.

Brauen, S. E., R. L. Goss, G. K. Stahnke and N. E. Jackson. 1990. Annual bluegrass (*Poa annua*) population decline with repeat applications of dithiopyr to bentgrass turf. p. 88. In 1990 Western Soc. Weed Sci. Proc., 43(1990). Sparks, NV.

Chapman, J.E., S.E. Brauen, G.K. Stahnke, and W.J. Johnston. 1992. Comparison of nitrate ion electrode and segmented flow analysis methods for nitrate ion concentration. p. 166. In Agron. Abstr. ASA, Madison, WI.

Stahnke, G.K., S.E. Brauen, and T.P. Riordan. 1992. Evaluation of improved buffalograss cultivars for use in the Pacific Northwest. p. 176. In Agron. Abstr. ASA, Madison, WI.

Proceedings:

Brauen, Stanton E. 1992. Zeolite as a cation exchange modifier. Proc. 45th Northwest Turfgrass Conf. 45: (In Press).

Brauen, Stan. 1991. Research report - Sulfur, phosphorus, calcium on putting turf. Proc. 44th Northwest Turfgrass Conf. 44:39-46.

Brauen, S. 1990. Can dithiopyr control *Poa*? Proc. West. Canada Turf Association Conf., Penticton, B.C., February 25-28, 1990. p. B1-B6.

Brauen, S. 1990. Turfgrass Research Development at WSU Puyallup. Proc West. Canada Turf Association Conf., Penticton, B.C., February 25-28 1990. p. G1-G3.

Brauen, Stan. 1990. Research report - Sulfur, phosphorus, calcium on putting turf. Proc. 44th Northwest Turfgrass Conf. 7 pp.

Chapman, Eric, S.E. Brauen, G.K. Stahnke and W. J. Johnston. 1992. Measuring nitrate movement in sand and modified rootzones. Proc. 45th Northwest Turfgrass Conf. 45: (In Press).

Chastagner, G.A, R. S. Byther, S. E. Brauen, G. K. Stahnke, and W. J. Johnston 1991. Management of necrotic ring spot in the Pacific Northwest. Proc. 45th Northwest Turfgrass Conf. 45:55-60.

Chastagner, G.A, J. Staley, and S. E. Brauen. 1991. Management of red thread in the Pacific Northwest. Proc. 44th Northwest Turfgrass Conf. 44:47-51.

Ekuan, A.J.A., and S.E. Brauen. 1992. Determination of nitrate concentration in soil leachate with a nitrate electrode. Proc. 45th Northwest Turfgrass Conf. 45: (In Press).

Goss, Roy L. and S. E. Brauen. 1991. Are there alternatives to annual meadow-grass, *Poa annua* L. Third National British and International Golf Greenkeepers Assoc., 7 pp.

Stahnke, G.K., S.E. Brauen, and G.D. Wingard. 1992. Turfgrass Research Update: Summary of the 1990 turfgrass survey and buffalograss update for 1992. Proc. 45th Northwest Turfgrass Conf. 45: (In Press).

Stahnke, G.K. 1991. Evaluation of buffalograss for use as a low maintenance grass in the Pacific Northwest. Proc. 45th Northwest Turfgrass Conf. 45:17-19.

Stahnke, G.K. 1991. Preliminary results of nitrogen fungicide movement through a Poa/bentgrass turf. Proc. 45th Northwest Turfgrass Conf. 45:20-23.

Stahnke, G.K. 1990. Recommended storage procedures for pesticides. Proc. Northwest Turfgrass Conf. 44:27-29.

Stahnke, G.K. 1990. Groundwater protection. Proc. Northwest Turfgrass Conf. 44:30-34.

Extension Publications:

Brauen, S. E. and G. K. Stahnke. 1992. 1992 turfgrass field day. Dept.of Soil and Crop Sciences, Washington State University, Technical Report No. 92-3. 45 pp.

Brauen, S. E., G. K. Stahnke, G. Chastagner, and R. L. Hummel. 1991. 1991 Turfgrass field day. Dept. of Crop and Soil Sciences, Washington State Univ. Technical Report #91-1, 51 pp.

Stahnke, Gwen K., S. E. Brauen, R. S. Byther, A. L. Antonelli, and G. C. Chastagner. 1992. Home lawns. WSU Coop. Ext. Bull. EB0482.

Stahnke, Gwen K. and Stanton E. Brauen. 1991. Annual bluegrass control in turfgrass for commercial applicators, EB1129. WSU Coop. Extension.

Stahnke, G. K. and S. E. Brauen. 1991. Annual bluegrass control in homelawns. WSU Coop. Extension. EB1600.

Stahnke, G. K. and S. E. Brauen. 1991. Turfgrass soil-water relationships. WSU Coop. Extension. EB1280.

Popular Publications:

Brauen, S., G. K. Stahnke, and R. Ingram. 1992. Pacific Northwest Lawn plan saves water. Western Turf Mgt. 3(6):26-28.

Brauen, S. 1991. Annual grasses can be controlled. Western Turf Management. 2(2):18-19, 34.

Brauen, S. E. and G. K. Stahnke. 1991. Principles of turfgrass management, water use and the healthy lawn. (Water conservation coalition of Puget Sound, Seattle Water Department, Everett Public Works Department, Tacoma City Water). 13 pp.

Brauen, S. E. 1990. Water usage by plants. 4pp. Center for Urban Horticulture, Univ. Washington. Special Publication for Irrigation and Water Use Seminar, Nov. 6, 1990.

Chastagner, G. A, R. S. Byther, S. E. Brauen, W. J. Johnston, and G. K. Stahnke. 1991. Management of necrotic ringspot in the Pacific Northwest. Turfline News 104:J1-9.

Chastagner, G. A, J. Staley, and S. Brauen. 1991. Management of red thread in the Pacific Northwest. Turfline News 104:K1-9.

APPENDIX A: STEERING ADVISORY COMMITTEE

Clint Lank, Manager, King County Environmental Division

Ann Dold, SEPA Section Chief, King County Environmental Division

Henry Shaw, Environmental Planner, King County Environmental Division

Gary Kohler, Manager, King County Subdivisions, Building and Land Development Division

Randy Schroers, Chief, King County Park Maintenance, Luther Burbank Park

Bill Eckel, Project Manager, King County Surface Water Management, Water Quality Program

Nota Lucas, Conservation Office, Seattle Water Department

Dr. Richard Horner, Director, Center for Urban Water Resources Management, Department of Civil Engineering at University of Washington

Gerry Adams, Audubon Society

Doreen Johnson, Washington Environmental Council

Hugh Goldsmith, Hugh J. Goldsmith and Associates

John Hempelmann, Caincross & Hempelmann

Richard Wilson, Hillis, Clark, Martin, and Peterson

Tom Wolff, President, Northwest Turf Grass Association

Skip Holman, Community Development Manager, Quadrant Development Corporation